MONTHLY 7/6

The Journal of THE ROYAL AERONAUTICAL SOCIETY

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NEW ZEALAND DIVISION—FIRST ANNUAL REPORT

LONDON
ROYAL AERONAUTICAL SOCIETY, 4 HAMILTON PLACE, W.1

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THE ROYAL AERONAUTICAL SOCIETY
GRADUATES' AND STUDENTS' SECTION

May 1950

ANNUAL GENERAL MEETING

The Fourteenth Annual General Meeting of the Graduates' and Students' Section was held in the Council Room at the Society, 4 Hamilton Place, W.1, on Friday, 24th March 1950, at 7 p.m. Eleven members of the Section were present.

Mr. J. W. F. Housego, the Section Chairman, presided. The minutes of the previous Annual General Meeting (March 1949) and of the Extraordinary General Meeting (October 1949) were confirmed.

As the activities of the Section during the first half of the year had been reported at the Extraordinary General Meeting, the Chairman's report covered only the period October 1949 to March 1950. The report (a summary of which is below) was read and adopted. Copies of the proposed Standing Orders for the Section were circulated and approved by the meeting after one minor addition.

A number of suggestions for future lectures, discussions and visits were made before the Chairman closed the meeting at 8.30 p.m.

CHAIRMAN'S REPORT

Since its formation, the new Graduates' and Students' Committee has had three meetings and has submitted formal terms of reference and standing orders for Council's approval.

The autumn session of lectures was being prepared; half of the lectures would be by members of the Section and half by well-known members of the Society and the Industry. Although the Society's "Section" Lectures were a competitive attraction to Graduates and Students (and had been well attended by them), the Committee felt that the Section should continue to hold its own meetings.

It was hoped that a number of visits would be made during the summer and negotiations were being made to ensure that members would be enabled to take part. The attendance at past visits had been disappointing and it was felt that Council would watch future events with interest.

The Section's page in the JOURNAL was progressing well and two of the papers had been re-printed in one of the national aeronautical periodicals; Mr. Bowden, who edited the page for the Section, still wanted more papers from members of the Section.

The Committee was investigating the possibilities of supplying teas at the Section's meetings and of issuing abridged pre-prints of some lectures.

A Committee of only five months' standing could not have much to report, but it was hoped that the next year's report would record far more satisfactory progress.

J. W. F. HOUSEGO
March 1950. (*Chairman*).

GRADUATES' AND STUDENTS' COMMITTEE

The following are the members of the Graduates' and Students' Committee of Council for the year June 1950 to June 1951:—

S. Scott Hall, *Fellow* (D.G.T.D.(A.), Ministry of Supply).
A. V. Cleaver, *Associate* (The de Havilland Engine Co. Ltd.).
J. W. F. Housego, *Graduate* (Handley Page Ltd.).
M. K. Bowden, *Student* (Northampton Engineering College).
M. C. Campion, *Graduate* (The Bristol Aeroplane Co. Ltd. (London)).
J. C. Gibbings, *Graduate* (Royal Aircraft Establishment).
F. G. Irving, *Graduate* (Imperial College).
J. R. Miller, *Graduate* (Hawker Aircraft Ltd.).
K. R. Warren, *Student* (The de Havilland Aircraft Co. Ltd.).

LIFT SPOILERS FOR LATERAL CONTROL

by

R. R. DUDDY, B.Sc., A.F.R.Ae.S.

PART II

(*Part I was published in April* 1950)

SLOT LIP AILERON

Another special type of lift spoiler is the slot lip aileron. In this case the spoiler is formed by the lip of the aerofoil at the slot of a slotted flap. The spoiler works by altering the slot gap and so spoiling the flow over the slotted flap. As might be imagined a powerful control can be obtained with flaps down but with flaps up the effectiveness of the spoiler is much reduced. In fact, with this scheme an additional spoiler or aileron would be required to give adequate rolling moments with flaps retracted. The hinge moments on the spoiler are large and tend to vary irregularly with control deflection, thus adding to the difficulty of balancing the control aerodynamically.

CONCLUSION

Even this brief summary of spoiler characteristics shows there are plenty of pitfalls to be avoided in designing a spoiler lateral control. If the complication of power operation can be tolerated then the difficult problems of control feel are automatically solved and a circular arc spoiler with some form of slot should give adequate lateral control over the whole speed range. Such an arrangement has not been tried in flight and, in fact, no lateral control relying on lift spoilers alone has proved entirely satisfactory. With pure spoiler control the overall lift is necessarily reduced when a rolling moment is applied and this characteristic has been continuously criticised by pilots. The actual displacement of the axis of roll from the plane of symmetry will be only about 10 per cent. of the span but repeated coarse use of the control, as happens during landings in gusty conditions, would cause an appreciable loss in height and would add to the difficulties of controlling the approach path. Since the height lost during rolling will be a function of the percentage lift change due to the spoilers, it seems probable that this characteristic would be less pronounced when using very ambitious high lift devices.

The spoiler controls which have proved most successful in flight have had small orthodox ailerons in addition to the spoilers. Inevitably this adds to the complication of the scheme and there is a small, but probably unimportant, restriction on the maximum lift increment from the flap.

The advantages of the combined scheme are:—

(*i*) The excellent response obtained from the aileron can be made to mask any lag or initial ineffectiveness of the spoiler.

(*ii*) The aileron can easily be made to provide "feel."

(*iii*) It is convenient for providing lateral trimming.

The Black Widow, an American night fighter, was an operational aircraft which used this lateral control scheme with success. The aileron occupied only 14 per cent. of the span and the circular arc spoiler was placed just forward of the leading edge of the slotted flap.

It is concluded that satisfactory lateral control using spoilers alone could be obtained, provided that they are operated by power to overcome the hinge moment and inertia problems. If power operation cannot be tolerated, satisfactory control can be obtained with short span ailerons used in conjunction with the spoilers. In this case it is recommended that the ailerons should have large chord (up to 0.4*c*), the spoilers being regarded merely as a device for augmenting the rolling power of the ailerons.

THE ROYAL AERONAUTICAL SOCIETY

4 HAMILTON PLACE, PICCADILLY, LONDON, W.1. GROSVENOR 3515-9

NOTICES MAY 1950

ANNUAL GENERAL MEETING

Voting members of the Society are reminded that the Annual General Meeting will be held on Monday, 15th May 1950, at 5.30 p.m., in the offices of the Society. The formal Notice calling the meeting was published in the April Notices.

GARDEN PARTY—14th MAY 1950

For the benefit of those who have not yet applied for tickets for the Garden Party (10s. each including tea) an application form is enclosed with the May JOURNAL (or these Notices).

As some members are not taking their full allocation of tickets, members who would like *more* than the four tickets to which they were originally limited, may apply for them; but this concession is only made conditionally on tickets being available, so early application is necessary.

There will be a special train from Paddington and special buses from Maidenhead Station to the Aerodrome. Special cheap rail tickets (5s. return) will be obtainable *from Paddington only* and bus tickets (1s. 6d.) *on the buses.*

The more leisurely flying days of the 1920s and 1930s—and before—of the flying programme will revive memories for many members and in addition there will be more modern aspects of flying and aeronautical activities and a remarkable display of valuable scale models showing the history of aircraft in Great Britain.

These scale models, over 200 in number, have been kindly lent by many of the firms in the Industry and organised for display by the Branches of the Society.

In the Flying Programme the following are some of the machines which it is expected will take part:—

The Stampe Squadron, the famous French team which has created aerobatic history; the Lunak L 107 and Olympia gliders; the French Fouga Cyclone light aeroplane with a jet engine which will be seen for the first time in this country; the Fokker S 12 from Holland and several other types from abroad; some of the very early types of British aircraft; an interesting collection of ultra-light aeroplanes and—a bigger balloon than in 1949!

WHITSUN HOLIDAYS

The Offices and Library of the Society will be closed from 5 p.m. on Friday, 26th May, to 9 a.m. on Tuesday, 30th May 1950, for the Whitsun holidays.

CLOSING OF THE LIBRARY

The Library will be closed on 31st May 1950 and on 1st and 2nd June 1950 because the Associate Fellowship Examinations will be held there.

CONTENTS OF THE MAY JOURNAL

Captain J. Laurence Pritchard, Hon.F.R.Ae.S., Hon.F.I.Ae.S.—An Appreciation.
Navigational Systems and Instrument Aids, Dr. D. E. Adams and Dr. A. M. Uttley.
The Producing of a Prototype Aircraft, C. T. Wilkins, A.F.R.Ae.S.
An Experiment in Flying Training, A. C. W. Rattle, A.F.R.Ae.S.
New Zealand Division of the Royal Aeronautical Society—First Annual Report.

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the JOURNAL *and hope that members and non-members of the Society will contribute papers on their own special subjects.*

THE AERONAUTICAL QUARTERLY—Volume II

Volume II, Part I of "The Aeronautical Quarterly" will be published in May.

The contents will be:—

Two-Dimensional Theory of Stiffened Plates	Chang O'Chou
The Whirling of a Spinning Top	J. Morris
The Possibility of the Determination of Rate of Climb from Acceleration Measurements in Level Flight ...	E. C. Pike
A Note on Subsonic Aerofoil Theory	John W. Miles
Theory of an Oscillating Supersonic Aerofoil	Geoffrey L. Sewell
The Linearised Theory of Conical Fields in Supersonic Flow, with Applications to Plane Aerofoils	S. Goldstein and G. N. Ward

Copies of Part I, Volume II will be available from the offices of the Society towards the end of May at 7s. 9d. each to members of the Society, post paid, or 10s. 3d. each to non-members, post paid.

Volume I of "The Aeronautical Quarterly" (copies of which are still available) has been well received both in Great Britain and overseas; the response has been encouraging and reviews published both in this country and the United States have praised and welcomed both the appearance and contents of the Society's new publication. It is hoped that the circulation will steadily increase, thereby enabling the contents of each number to be still further improved and enlarged.

The special attention of members is drawn to the fact that a strictly limited edition only of "The Aeronautical Quarterly" is printed and numbers can not be reprinted in any circumstances. An annual subscription is therefore advisable.

38th WILBUR WRIGHT LECTURE—SPECIAL NOTICE

The 38th Wilbur Wright Memorial Lecture will be held at the **Royal Institution, 21 Albemarle Street, W.1,** on 25th May 1950, at 6 p.m., and *not* at The Institution of Civil Engineers. The Lecture will be given by Sir Richard Fairey, M.B.E., F.R.Ae.S., on "Some Aspects of Expenditure on Aviation."

THE BUSK STUDENTSHIP IN AERONAUTICS

There is a vacancy for the Busk Studentship in Aeronautics for 1950. Application forms may be obtained from the Professor of Aeronautical Engineering, Engineering Laboratory, Cambridge, to whom they must be returned by the 1*st June* 1950.

This Studentship was established in memory of Edward Teshmaker Busk who lost his life in 1914 while flying an experimental aeroplane. The Studentship is of the value of about £3,000, tenable for one year from 1st October 1950. It is open to any man or woman who is a British subject and of British descent who has not

attained the age of 25 years on 1st October 1950. The object of the Studentship is to enable the holder to engage in research, or preparation for research, in aeronautics of the type in which Edward Busk was especially interested, that is, of the type involving experimental as well as mathematical investigation.

LECTURES

Thursday, 4th May 1950—3rd LOUIS BLERIOT LECTURE—IN PARIS. Towards Slower and Safer Flying, Improved Take-off and Landing and Cheaper Airports. Sir Frederick Handley Page, C.B.E., F.I.Ae.S., Hon.F.R.Ae.S.

Thursday, 25th May 1950—38th WILBUR WRIGHT MEMORIAL LECTURE, Some Aspects of Expenditure on Aviation, Sir Richard Fairey, M.B.E., F.R.Ae.S.—**at The Royal Institution, 21 Albemarle Street, W.1, at 6 p.m.**

WEYBRIDGE BRANCH

Wednesday, 31st May 1950—Annual General Meeting.
At Vickers-Armstrongs Ltd., Weybridge Works, at 6 p.m., unless previous notice is given.

ELECTIONS

The following is a list of new members and transfers of membership of the Society:—

Associate Fellows

Kenneth John Powell, Frank Myles Temple Reilly, John Seddon.

Associates

Cecil David Melville Kingsford, Henrey William Owen, Richard Woollaston Parr, John Horace Evelyn Numa Rahr, Arthur John Smaill.

Graduates

Francis Edgar Bartholomew, William Alan Fox, George Frederick Gilmore, John Charles Hodge, Kenneth Brian Jepson, Raymond Leslie Wheeler.

CHANGES OF ADDRESS

To assist in keeping the records of members correct and up to date the Secretary will be glad if all members will notify him as soon as possible of changes of address.

When notifying changes please give the following particulars:—

Name (in block letters).
Grade of membership.
New address (in block letters).
Old address.

Changes of address must be received *before the 15th of the month* in order to be effective for the Journal for the following month.

LAPEL BADGES

Lapel badges are still available to members at 3s. 6d. each, including postage. These badges are gilt enamel with a screw back and are $\frac{3}{4}$ inch in diameter. Remittances should be sent, with applications, to the Secretary at the Offices of the Society.

JOURNAL BINDING

The prices of binding of Journals is as follows:—

1949 Volume (including packing and postage), 15s. 6d.

Previous Volumes (including packing and postage), 17s. 0d.

Journals should be sent direct to the Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the offices of the Society.

Cases only for unbound 1949 Volumes are available, price 6s. 6d. each. Requests for cases, with remittances, should be sent to the Secretary at the offices of the Society.

ACKNOWLEDGMENTS

The Council acknowledge with grateful thanks the gift of books from Air Commodore F. R. Banks, *Fellow*, and J. A. C. Williams, Esq., *Associate Fellow*.

ADDITIONS TO THE LIBRARY

The following have been added to the Library (titles of Pamphlets are printed in italics and books marked * or ** may not be taken out on loan):

Airline Competition. F. W. Gill and G. L. Bates. Harvard University. 1949.

Aircraft Structures. D. J. Peery. McGraw Hill. 1950.

Aircraft Uses in 1947. Civil Aeronautics Administration. Civil Aeronautics Administration. 1949.

Engineering Structures. A. G. Pugsley and D. R. Rexworthy (Editors). Butterworth. 1949.

Engineering Supersonic Aerodynamics. E. A. Bonney. McGraw-Hill. 1950.

Fluid Pressure Mechanisms. H. G. Conway. Pitmans, London. 1949.

Gas Turbines and Jet Propulsion. 5th Edition. G. G. Smith. Iliffe and Sons. 1950.

Mechanical Properties of Metals and Alloys. J. L. Everhart and others. U.S. National Bureau of Standards. 1943.

The R.C.A.F. Overseas. Sixth Year. Oxford University Press, Canada. 1949.

The Soviet Air Force. Asher Lee. Duckworth. 1950.

N.A.C.A. Technical Notes

1220—*Effect of exhaust pressure on the performance of an 18-cylinder air-cooled radial engine with a valve overlap of 40 degrees. S. D. Boman, T. F. Nagey and R. B. Boyle.*

1221—*Effect of exhaust pressure on the cooling characteristics of an air-cooled engine. M. F. Valerino, S. J. Kaufman and R. F. Hughes.*

1222—*Buckling stresses of simply supported rectangular flat plates in shear. M. Stein and J. Neff.*

1223—*Critical combinations of shear and direct stress for simply supported rectangular flat plates. S. B. Batdorf and M. Stein.*

1999—*A theoretical analysis of elastic vibrations of fixed-ended and hinged helicopter blades in hovering and vertical flight. Morris Morduchow.*

2000—*Data on shape and location of detached shock waves on cones and spheres. J. W. Heberle, G. P. Wood and P. B. Gooderum.*

2001—*Aerodynamic characteristics of damping screens. G. B. Schubauer, W. G. Spangenburg and P. S. Klebanoff.*

2002—*Application of the Laplace transformation to the solution of the lateral and longitudinal stability equations. G. A. Mokrzycki.*

2003—*Investigation of a NACA high-speed strain-gauge torquemeter. J. J. Rebeske, Jnr.*

2004—*An investigation of the stability of a system composed of a subsonic canard airframe and a canted-axis gyroscope automatic pilot. R. A. Gardiner, J. Zarovsky and H. O. Ankenbruck.*

2005—*A theoretical analysis of the effect of time lag in an automatic stabilization system on the lateral oscillatory stability of an airplane. L. Sternfield and O. B. Gates, Jnr.*

2006—*A theoretical investigation of the effect on the lateral oscillations of an airplane of an automatic control sensitive to yawing accelerations. A. R. Beckhardt.*

2007—*The load distribution due to sideslip on triangular, trapezoidal and related plan forms in supersonic flow. A. L. Jones and A. Alksne.*

2008—*The design, operation, and uses of the water channel as an instrument for the investigation of compressible-flow phenomena. C. W. Matthews.*

2010—*Effect of horizontal tail on low-speed static lateral stability characteristics of a model having 45 degrees sweptback wing and tail surfaces. J. D. Brewer and J. H. Lichtenstein.*

2011—*Spanwise loading for wings and control surfaces of low aspect ratio. J. DeYoung.*

2012—*Results of shear fatigue tests of joints with 3/16-inch-diameter 24S-T31 rivets in 0.064-inch-thick alclad sheet. M. Holt.*

2013—*A study of the use of experimental stability derivatives in the calculation of the lateral disturbed motions of a swept-wing airplane and comparison with flight results. J. D. Bird and M. B. Jaquet.*

2015—*Water landing investigation of a model having a heavy beam loading and a 30 degrees angle of dead rise. S. A. Batterson and A. E. McArver.*

2016—*Floating characteristics of rudders and elevators in spinning attitudes as determined from hinge-moment-coefficient data with application to personal-owner-type airplanes. W. Bihrle, Jnr.*

2017—*A small-deflection theory for curved sandwich plates. M. Stein and J. Mayers.*

2018—*Low-speed investigation of a thin, faired, double-wedge airfoil section with nose flaps of various chords. L. M. Rose and J. M. Altman.*

2019—*Penetration of airjets issuing from circular, square, and elliptical orifices directed perpendicularly to an air stream. R. S. Ruggeri, E. E. Callaghan and D. T. Bowden.*

2020—*Compressive strength of flanges. W. Z. Stowell.*

2021—*Buckling of thin-walled cylinder under axial-compression and internal pressure. Hsu Lo, H. Crate and E. B. Schwartz.*

2022—*Propeller flight investigation to determine the effects of blade loading. J. B. Hammack and A. W. Vogely.*

2023—*Determination of the rate of roll of pilotless aircraft research models by means of polarized radio waves. R. O. Harris.*

2025—*Effect of valve overlap and compression ratio on variation of measured performance with exhaust pressure of aircraft cylinder and on computed performance of compound power plant. C. S. Eian.*

2026—*Tables for determined reduction of energy and intensity of x-rays and gamma-rays at various scattering angles in small thicknesses of matter. G. Allen.*

2028—*Effect of tunnel configuration and testing technique on cascade performance. J. R. Erwin and J. C. Emery.*

2029—*The interpretation of biaxial-tension experiments involving constant stress ratios. S. B. Batdorf.*

2030—*Variation with temperature of surface tension of lubricating oils. S. Rose.*

2031—*Comparative foaming characteristics of aeronautical lubricating oils. W. W. Woods and J. V. Robinson.*

2032—*Foaming of mixtures of pure hydrocarbons. J. V. Robinson and W. W. Woods.*

2033—*Rise of air bubbles in aircraft lubricating oils. J. V. Robinson.*

2036—*Charts of airplane acceleration ratio for gusts of arbitrary shape. B. Mazelsky.*

2042—*Time-dependent downwash at the tail and the pitching moment due to normal acceleration at supersonic speed. H. S. Ribner.*

N.A.C.A. Technical Memoranda

1131—*Gas-dynamic investigations of the pulse-jet tube. Parts I and II. F. Shultz-Grunow.*

1256—*The boundary layers in fluids with little friction. H. Blasius.*

N.A.C.A. Reports

876—*The stability of the laminar boundary layer in a compressible fluid. Lester Lees.*

891—*A thermodynamic study of the turbojet engine. B. Pinkel and I. M. Karp.*

892—*Damping in pitch and roll of triangular wings at supersonic speeds. C. E. Brown and Mac C. Adams.*

897—*Knocking combustion observed in a spark-ignition engine with simultaneous direct and Schlieren high-speed motion pictures and pressure records. G. E. Osterstrom.*

898—*A unified theory of plastic buckling of columns and plates. E. C. Stowell.*

901—*Analysis of effect of basic design variables on subsonic axial-flow-compressor performance. J. T. Sinette.*

902—*Subsonic flow over thin oblique airfoils at zero lift. R. T. Jones.*

904—*Estimation of F-3 and F-4 knock-limited performance ratings for ternary and quaternary blends containing triptane or other high-antiknock aviation fuel blending agents. H. C. Barnett.*

911—*Lifting-surface-theory aspect-ratio corrections to the lift and hinge-moment parameters for full-span elevators on horizontal tail surfaces. R. S. Swanson and S. M. Crandall.*

923—*Effect of afterbody length and keel angle on minimum depth of step for landing stability and on take-off stability of a flying boat. R. E. Olsen and N. S. Land.*

A.R.C. Reports and Memoranda

2034—*Extension of glider two cable theory to elastic cables subject to air forces of a generalised form. F. O'Hara.*

College of Aeronautics

33—*The diffusion of loads in non-rigid circular frames. S. R. Lewis.*

Commonwealth of Australia

SM. 140—*Cylindrical tubes with cut-outs under arbitrary loading. J. J. Thompson.*

Translation No. 12—*Singular integral equations. N. I. Muckhelishvili. Translated by J. R. M. Radok and W. G. Woolnough.*

Publications Scientifiques et Techniques du Ministere de l'Air

236—*Contribution a l'emploi des méthodes optiques en métallographie microscopique. T. Cambon.*

B.S.2. 113—*Restitution planimétriques des photographies aériennes. B. Dubuisson.*

J. LAURENCE PRITCHARD,
Secretary.

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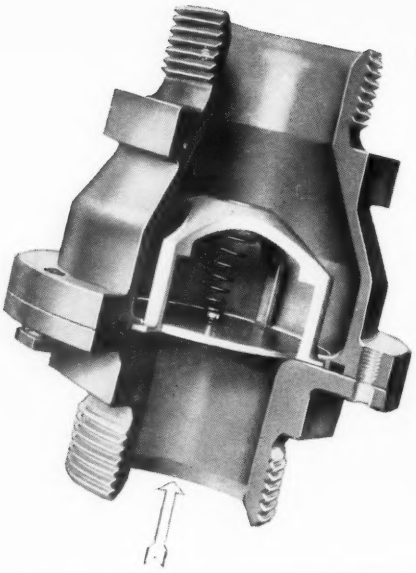

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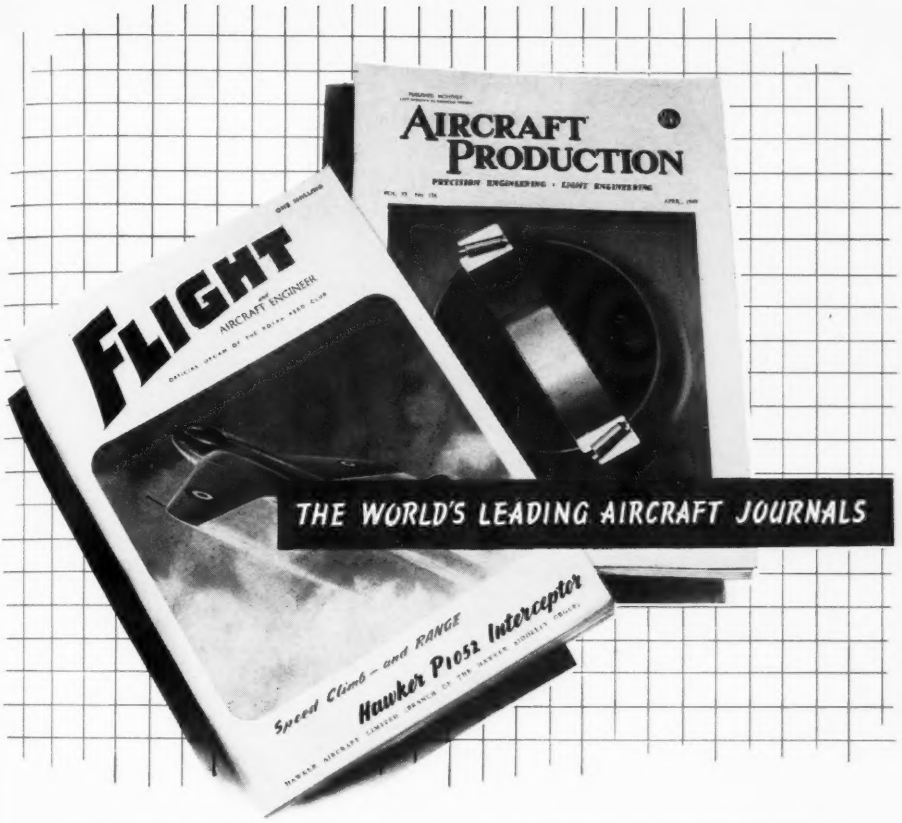

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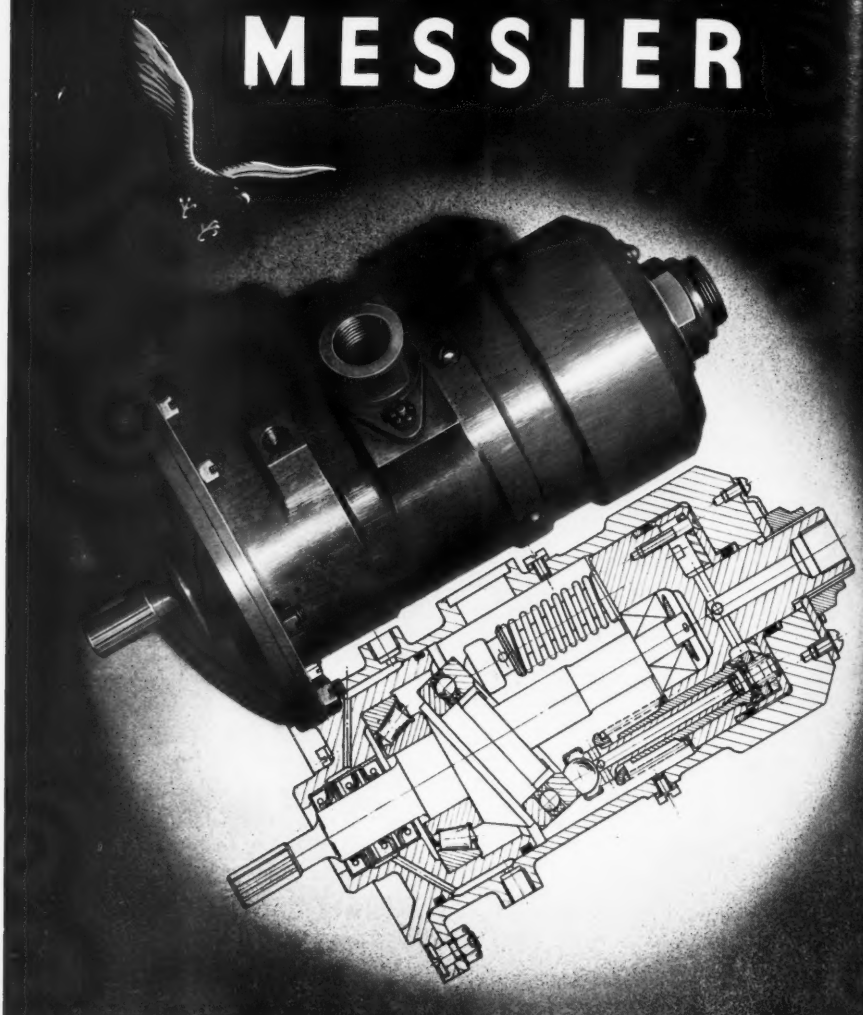

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THE AERONAUTICAL QUARTERLY

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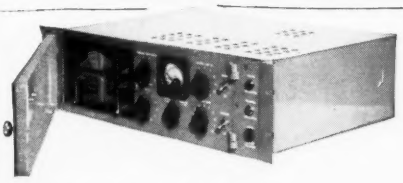

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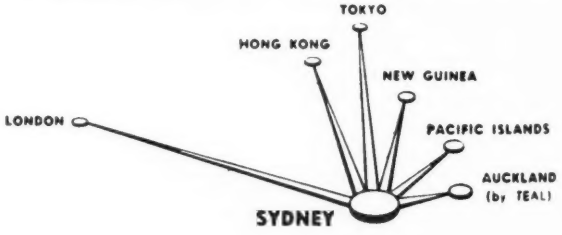

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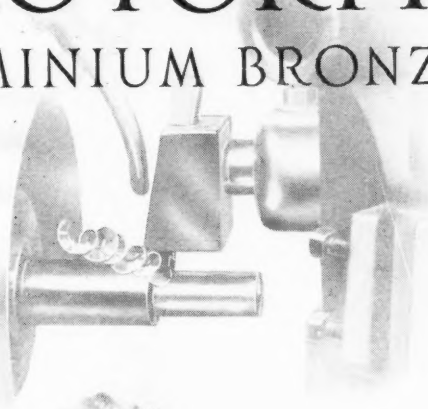

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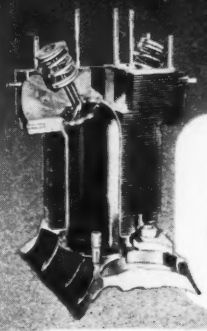

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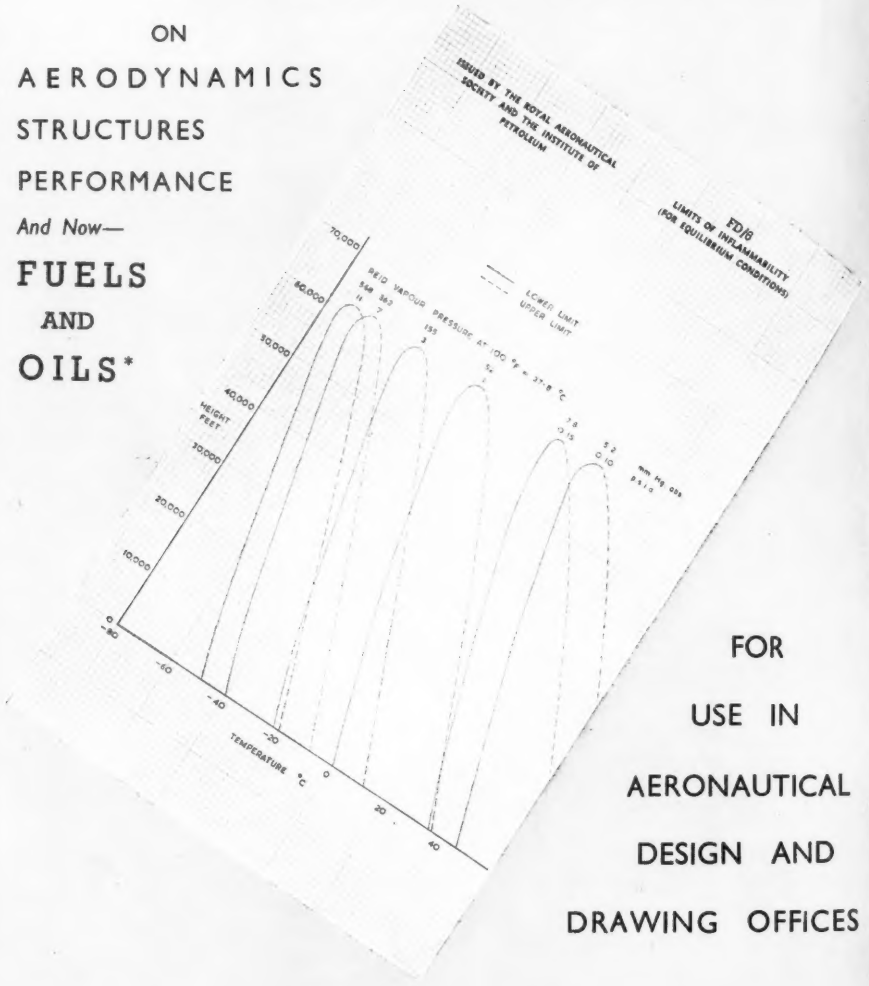

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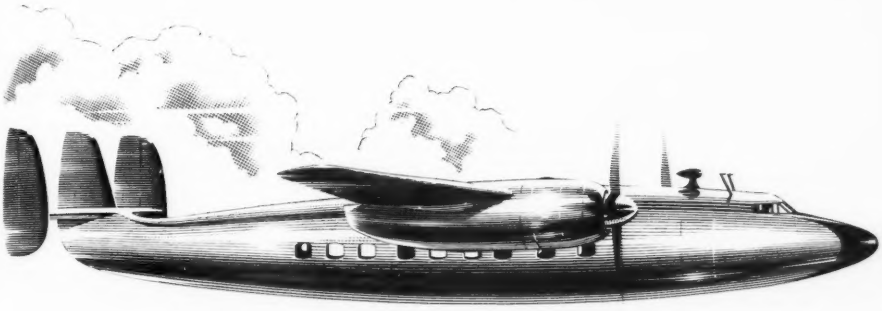

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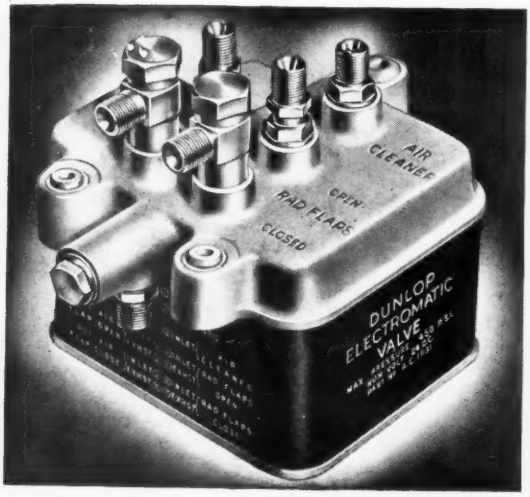

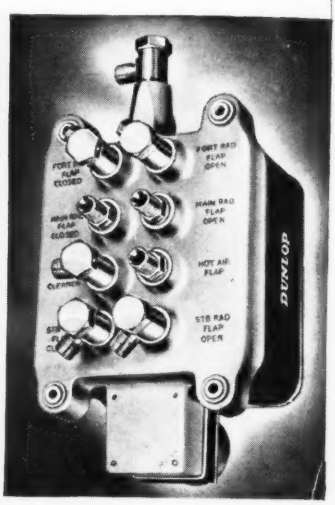

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THE ROYAL AERONAUTICAL SOCIETY has been singularly fortunate in those who have served it since its foundation on 12th January 1866.

Many on its Councils, and most of its members, during those first decades when the aeroplane was but a theoretical vision, kept the light of endeavour shining brightly despite the despairing winds of hope deferred.

Captain J. Laurence Pritchard was fortunate in being called upon to serve the Society during the vigorous youth of aviation, a youth which had already tried its fledgling wings in war, a youth which was eager for conquest, a youth which had tasted the savour of high adventure in the skies and had seen the earth beneath its gaze, after long æons of the world's history.

The Society may count itself fortunate too, for in Captain Pritchard it found a man who, during the years he served it, never lost that spirit of youth, one who looked ahead with a serene confidence in the future of aviation and of the Society.

Laurence Pritchard was educated at Dulwich College and Christ's College, Cambridge, where he passed the Mathematical Tripos examination. At Dulwich he was a contemporary of the brothers H. M. Cave-Brown-Cave (now Air Vice-Marshal) and T. R. Cave-Brown-Cave (Wing Commander) and of the late Harris Booth, who played a leading part in the development of the aeroplane for the Navy in the 1914-18 War and taught the future Secretary of the Society the mysteries of the flight of the boomerang.

After coming down from Cambridge Laurence Pritchard entered Fleet Street and wrote with the authority of youth on most subjects, including aviation. He wrote his first articles on aviation in 1909, that year which was in so many ways the most remarkable year in aviation, for it was the year the Wright Brothers flew in France and roused the imagination of the world, that Bleriot flew the Channel, that the great aviation meeting at Rheims was held, and the year when the Council of the Society issued a warning to the public against investing money in aeronautical companies without first making thorough enquiries into such concerns!

In February 1910, less than seven years after the first heavier-than-air flight, Laurence Pritchard wrote an article comparing the still fledgling aeroplane with the giant Zeppelin and firmly stated his youthful conviction that the "gas-bags" would not survive.

It was not until the First World War, however, that aviation fully claimed him. Although he had joined the Army, a chance meeting with Harris Booth brought about a sudden transfer above the Admiralty Arch and to the Royal Naval Air Service, in that famous Room 1,004 which did so much for the development of Naval aircraft under Admiral Murray Sueter, Commander Clark Hall, A. J. S. Pippard, Harris Booth, Harold Bolas, Tom Barlow, F. A. Bumpus and many others. Later, when the Royal Air Force was formed, he was transferred to it, and is one of the few people who has served with all three Services.

H. G. Conway

CAPTAIN J. LAURENCE PRITCHARD, Hon.F.R.Ae.S., Hon.F.I.Ae.S.

In those few years of war the Secretary learnt more about aviation, as indeed did everyone else, than during twice as many years of peace. And in those years he was bitten by that aviation bug which leaves behind it a fever, never cured, although relieved from time to time by strong doses of aviation medicine.

As a mathematician thrown among engineers Laurence Pritchard found life, if not to say difficult, at least exciting. To be asked to calculate the strength of an aeroplane from general arrangement drawings, when a blue print to him was a novel way of picturing an aeroplane and a slide rule was a mysterious way of showing twice two were four, was something without precedent in those days. That he must have succeeded may be inferred from the fact that he became, with A. J. Sutton Pippard, who had taught him all he knew, one of the authors of the original "Hand-book of Strength Calculations," the forerunner of the now well-known A.P. 970.

The names of Pippard and Pritchard were to become even better known in 1920 when they published "Aeroplane Structures," a book which for years was the aircraft stressman's bible in America as well as in Great Britain.

In 1919 Captain Pritchard became Editor of the JOURNAL of the Society which had been issued first as a Quarterly in 1897 and as a monthly in 1918.

For the next six years, as Editor of the JOURNAL, Captain Pritchard was also a member of Council and during those years he helped in the taking of certain steps which were ultimately to have a great effect on the prestige and power of the Society. The first of these was the institution of examinations for Associate Fellowship, which came into force in April 1922. A member of the Examinations Committee for many years, the Secretary did everything possible to encourage the raising of the standard until now the Associate Fellowship examination is a qualification widely recognised.

It had been expected when the 1914-18 War was over that aviation would go ahead fast and that all the world would be flying in a few years along the great air routes which had been visualised. Unfortunately interest in aviation lessened. The membership of the Society, which had reached well over 1,000 by the end of 1918, began to decline, despite all the efforts of the Council, which included the holding of the International Air Congress of 1923 organised by the Council and so ably run by Lt.-Col. Lockwood Marsh. By the end of 1924 it was clear that drastic steps must be taken to conserve the Society's resources, Captain Pritchard was asked to take over the Secretaryship in an honorary capacity on 1st April 1925.

In 1925 the Council issued rules for the formation of Branches and the first English Branch under these rules was founded at Coventry. From that small beginning there are now nineteen Branches of the Society in Great Britain and Canada and Divisions of the Society in Australia, New Zealand and South Africa. The Branch membership has risen from some 200 in 1926 to well over 5,000 at the present time.

The year 1925 saw a real turning point in the Society's long history. During that year Harry Guggenheim visited the Society's headquarters and as a result of his inquiries into the work of the Society the Danial Guggenheim Fund made a grant of $5,000, a grant which was renewed for the next four years. On the advice of the Secretary much of this sum was spent on improving the JOURNAL, issuing a consolidated Subject Index of the first thirty volumes and a catalogue of the books in the library. An appeal was also issued for an Endowment Fund to enable the Society some day to acquire a home of its own.

Both the Air Ministry and the S.B.A.C. helped the Society with grants. Laurence Pritchard visited the leading firms in the Industry, stressing the importance of a strong and flourishing Society to the future of the Industry. Many firms, as a result, agreed to pay the examination fees for successful Associate

Fellowship candidates as well as the first year's subscription, a gesture which added greatly to the Society's membership.

In 1927 the Society and the Institution of Aeronautical Engineers were amalgamated and Captain Pritchard was appointed full-time Secretary.

During the two years he had served in an honorary capacity the membership had ceased to drop, and the Council were able to plan ahead with some confidence. The work of drafting new rules, editing the JOURNAL and other periodicals and the beginnings of a technical index had all been carried out by the Secretary.

A prominent part was taken by the Society in the 1929 Aeronautical Exhibition held at Olympia. For it Mr. J. E. Hodgson, the Honorary Librarian, in a most generous fashion put at the disposal of the Society his remarkable and unique collection of historical prints, books and MSS, since acquired by the Society. With his ever-ready help, Captain Pritchard continually fostered the historical side of the Society and during the years which followed never lost an opportunity of acquiring additions to the Society's now unique collection.

In 1930 the Secretary visited Canada and the United States of America, a visit which was fraught with far-reaching consequences for the Society. In Canada he assisted in the founding of Branches of the Society in Ottawa and Montreal.

In New York the Secretary attended a dinner given to him by Major Lester Gardner, Edward Warner, J. C. Hunsaker and other leaders of American aviation and, at their request, outlined to them the work and organisation of the Royal Aeronautical Society. Out of the advice and help he then gave came the Institute of the Aeronautical Sciences. A chain was forged then, the links of which have grown stronger with the years. Through that 1930 visit more and more close Anglo-American friendships are being formed yearly and in 1947 there took place the first of the meetings between the two bodies which are now being held biennially in London and New York.

Following his visit to Canada and the United States, the Secretary in 1931 inaugurated lectures to the public schools and other educational centres and with immense energy himself gave over 100 lectures in less than three years to drive home the gospel of the air. He also prepared a number of these lectures, complete with slides, and induced many members of the Society also to give them. In those three years the name of the Society became widely known and in 1935 the membership reached 1,500 for the first time. That year the first Annual Garden Party was held.

In the Sixty-ninth Annual Report of the Council, the President and Council put on record "their profound appreciation of the work of the Secretary, Captain J. Laurence Pritchard, who has not only rendered the greatest service to the Society as in previous years, but has identified himself generously with every movement that appertains to its benefit and prestige."

In the Seventieth Annual Report of the Council there appeared the following: "This Report would not be complete without a tribute of thanks to our Secretary, Captain Pritchard, for all his work, advice, and energy in the interests of our body. This is no mere formal acknowledgment, but one of real thanks to one we look upon as almost the human embodiment of the Royal Aeronautical Society."

The end of 1935 saw the Endowment Fund reach £10,000 and a further drive in preparation to achieve the object which had constantly been held before the members, the acquisition of a building worthy of the rapidly growing prestige and influence of the Society.

The Council now felt justified in looking for new premises, although it was nearly three years before they were found. During that period the Secretary visited and reported on numerous possible buildings.

Late in 1938 No. 4 Hamilton Place was acquired, was occupied on 25th March 1939 and formally opened on 16th and 17th June 1939. In 1938 the membership had reached 2,000 and by the end of 1939 it was close on 2,500.

Less than three months after the formal opening of the first home of the Society the Second World War had begun.

During the whole of the war No. 4 Hamilton Place was kept open to its members. Immediately on the outbreak of hostilities arrangements were made for an emergency headquarters in the country in case the bombing of London made it impossible to remain. The historic records of the Society were transferred there for safety, as well as irreplaceable books and records. It is no longer a secret that the country headquarters of the Society was the Secretary's own home. Both No. 4 Hamilton Place and the Secretary's house suffered severely from bomb damage before the war was over, but without loss of any of the Society's records.

For the Secretary those were days of strenuous endeavour. Upon his shoulders fell much of the burden and responsibility for running the Society at a time when it was difficult for the Council and its Committees to meet.

During those early days of the war the work of the Society actually increased, as did the membership, and that work had to be carried on with a heavily reduced staff. Although the lecture programme, with the exception of the Wilbur Wright Lecture, was cancelled both on account of security reasons and the heavy demands made upon all in the Industry, the Council, with the consent of the Air Ministry and the Ministry of Production, arranged a number of secret week-end meetings on subjects of importance to the war effort.

These meetings involved the most careful preparation and organisation by the Secretary, with the ready help of many firms in the Industry. They were arranged in order to link together the experiences of various R.A.F. Commands, Fighter, Coastal, Bomber, Maintenance and the Fleet Air Arm, with the work of the designers and producers in the Industry. For the first time producers and users were brought into direct contact at a time of great value to both, and there is no doubt those meetings were among the most valuable the Society has ever staged.

In addition to those meetings secret technical Committees were appointed on Structures and Aerodynamics, to reduce the great mass of information on both subjects into useful form for the Industry. The Secretary of the Society, officially, is secretary of all Committees of Council, and during those urgent days of war, when Captain Pritchard had no one to assist him, that meant a considerable strain.

In addition to running single-handed those special Committees and meetings and the normal routine work of the Society, Laurence Pritchard was secretary of the Advisory Committee of the Council, which from 1941 to the end of the war prepared memoranda on highly secret matters and reported directly to the Ministers of Aircraft Production. Many of those memoranda had to be prepared in the first instance by Captain Pritchard from notes given to him by members of the Committee, on subjects which were of a highly specialised character.

During the whole of the war period the protection of the Society's building was in the hands of the Secretary and his staff under conditions which were extremely difficult at times. Bombs dropped near No. 4 Hamilton Place on seven different occasions and blew in windows and doors. Throughout those days, however, none of the work was delayed, work which apart from that already mentioned was greatly increased by the rapid increase in membership. From September 1939 to December 1945 the membership rose from 2,200 to over 5,000. During the greater part of the war a duplicate register was kept in the country in case of total destruction at headquarters.

Increased secrecy regulations, paper, labour and other restrictions handicapped severely the editing of the JOURNAL by the Secretary, but it appeared throughout

each month with a constantly increasing circulation. It is of interest to note that the JOURNAL is bought by the government departments of many countries and is subscribed for in most countries throughout the world.

Laurence Pritchard had always held that aviation was international and he took every opportunity to encourage that outlook so far as the Society was concerned, always urging closer links with other aeronautical bodies. It was during his term as Secretary that the British Empire Lecture, at the suggestion of Mr. George Dowty, was founded, the Bleriot Lecture was inaugurated, the Anglo-American Aeronautical Conference was begun and finally, the Divisions of the Society came into being in Australia, New Zealand and South Africa.

The great majority of present-day members of the Society have known no other secretary than Captain Pritchard, and few who have joined the Society in the past twenty years can be aware that he gave up a successful career as an author when he accepted the Council's invitation to become the Secretary.

At the end of the 1914-18 War Captain Pritchard had returned to Fleet Street and began to write detective stories and quickly became widely known. Altogether thirty novels came from his pen, a number of which were published first as serials in the London *Daily Mail*, *Evening News* and other daily papers. In another genre Captain Pritchard wrote many novels and stories for weekly magazines making a special appeal to women.

Inevitably the energy and time he gave to build up the Society took away from those formerly given to fiction.

Some measure of the astonishing energy and variety of his interests, largely unknown save to his closest friends, may be guaged from the fact that in the years between the two world wars he not only edited the JOURNAL of the Society, lectured widely on aeronautics on behalf of the Society he was running and wrote over thirty novels and close on a hundred short stories, but he was the science editor of the "Universal Encyclopedia" for which he wrote many of the science articles, the technical editor of the "Wireless Encyclopedia," the technical editor of the "Handbook of Aeronautics" and the first author of the section on Structures, an associate editor of the "Household Encyclopedia," the author of the "Book of the Aeroplane" and a text book on "Broadcast Reception in Theory and Practice," and an authority on criminology, on which subject alone he has written half a dozen well-known books and many hundreds of articles.

That might well be enough for one man but in the early twenties Captain Pritchard not only designed and built his own house, starting from a bare field in the heart of the country and finishing with the completely furnished article, but he took over a thousand photographs of the work in progress to show others how it could be done.

In addition to those many accomplishments he is an authority on the line-engraved stamps of Great Britain, and on Anglo-American poetry.

His other literary activities include a history of the Society, which was published in connection with the 80th Anniversary of the Society, and he is the author of all the programmes for the Society's Garden Parties, in verse and prose. Because of his witty and amusing pen the Garden Party Programmes are becoming "collectors" pieces.

That, briefly, is a history of the career of Laurence Pritchard, but it is also the history of the Society during the past 30 years, for during those years it climbed to its present eminence largely through the activities of one man—the Secretary. Presidents and Councils have come and gone but the Secretary has been the continuing link. During those years the name of Laurence Pritchard has become synonymous with that of the Society. As Council so aptly said in 1934-35 "one we

look upon as almost the human embodiment of the Royal Aeronautical Society"; and how much more true it is in 1950.

Mathematician, author, poet; a man of boundless energy and spirit and of infinite variety; such is Laurence Pritchard. His capacity for work and his ability to work quickly, grasping immediately the essentials of whatever he is doing, is astonishing—as is his memory. Quick to make up his mind on some things, he will ponder for long before taking any far-reaching decision but once his mind is made up and he believes his decision is right, he is immovable, whatever the cost to himself. Unconventional, and unorthodox in his attitude to life in general, he is a man of high principles and integrity, a staunch and loyal friend and has a sense of humour that, at times, is devastating. Never happier or more alive than when he is fighting battles, but never for himself; a quick, alert mind absorbing knowledge of every sort, a ready sympathy for the troubled and unfortunate, but impatient with the blind and foolish, a sturdy belief in aviation and an unquenchable faith in the Society, what it should stand for in the world and in the Industry—and what its members owe to that Society; these are some of the qualities which have kept him younger in spirit than many a man of half his years, made him difficult to understand at times to some, but gained him many friends.

The affection and esteem in which he is held in the United States were warmly demonstrated at every opportunity during the second Anglo-American Conference in New York in 1949. And the many letters received at the Society since the news of his retirement was announced, show the high place he holds in the Industry and among the members of all grades of the Society who pay tribute to both his well-known and lesser-known qualities. Many members have cause to be grateful for the generous assistance and unbiased advice he has given on many occasions. To have worked with him and for him at any time in the past 30 years has been both a privilege and an education.

The Society has been nobly served and has been fortunate indeed in having in Laurence Pritchard one of the outstanding personalities of aviation as its Secretary.

"The Council of the Royal Aeronautical Society feel that all those who have the privilege of membership of the Society, as well as others who are active in many branches of aviation and have knowledge of Laurence Pritchard's work over the past thirty years, would wish to raise a testimonial to him for presentation on his retirement in recognition of the high esteem in which he is held."

The above paragraph is quoted from a letter which has been issued and signed by the President, Sir John Buchanan, and the five Past-Presidents now on the Council. The letter is given in full overleaf.

TESTIMONIAL TO THE SECRETARY OF THE ROYAL AERONAUTICAL SOCIETY J. LAURENCE PRITCHARD, Hon. Fellow

DEAR SIR,

The Secretary, Captain J. Laurence Pritchard, is retiring in the near future.

Laurence Pritchard was appointed Editor of the JOURNAL of the Society in 1919, Honorary Secretary in 1925 and Secretary in 1927.

In his twenty-five years of service as Secretary he has seen the membership grow from 700 to over 7,000; the subscription income from £1,900 to £21,000; the formation of Branches, now totalling 19, in Britain and Canada; Divisions in Australia, New Zealand and South Africa; the inauguration of an Endowment Fund; and the acquisition by the Society of a house of its own for the first time in its history.

The growth of the Society, its present wide influence and high reputation; the range of its activities from the issue of monographs and data sheets to the Anglo-American Conferences; and annual Flying Garden Parties, owe much to the work of Laurence Pritchard over the years —and to his great personal qualities.

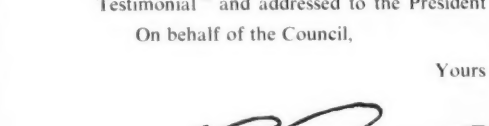
The Council of the Royal Aeronautical Society feel that all those who have the privilege of membership of the Society, as well as others who are active in many branches of aviation and have knowledge of Laurence Pritchard's work over the past thirty years, would wish to raise a testimonial to him for presentation on his retirement in recognition of the high esteem in which he is held.

Your contribution is invited and it will, we feel sure, interest you to know that the Society of British Aircraft Constructors have already agreed to send a donation of £500.

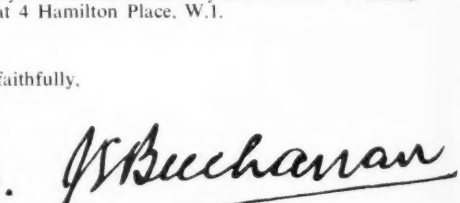
Cheques should be made payable to the Royal Aeronautical Society and crossed " Pritchard Testimonial " and addressed to the President at 4 Hamilton Place, W.1.

On behalf of the Council,

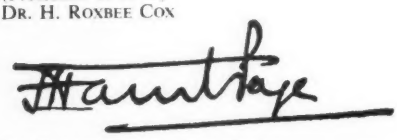
Yours faithfully,



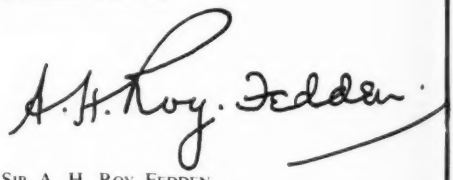
(President 1947-49)
DR. H. ROXBEE COX



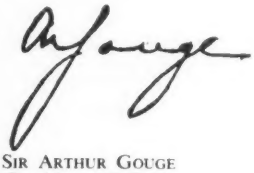
SIR JOHN S. BUCHANAN
(President 1949-50)



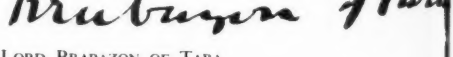
SIR FREDERICK HANDLEY PAGE
(President 1945-47)



SIR A. H. ROY FEDDEN
(President 1938-40, 1944-45)



SIR ARTHUR GOUGE
(President (1942-44)



LORD BRABAZON OF TARA
(President 1934-36)

(Members of the Council 1950)

NAVIGATIONAL SYSTEMS AND INSTRUMENT AIDS

by

Dr. D. E. ADAMS
and
Dr. A. M. UTTLEY

A joint meeting of the Royal Aeronautical Society and the Institute of Navigation was held at the Institution of Civil Engineers, Great George Street, London, S.W.1, on 15th December 1949. The 789th Lecture to be read before the Society was given by Dr. D. E. Adams and Dr. A. M. Uttley on Navigational Systems and Instrument Aids.

Sir John Buchanan, C.B.E., F.R.Ae.S., President of the Royal Aeronautical Society, presided and was accompanied by Sir Robert Watson-Watt, C.B., D.Sc., LL.D., F.R.S., F.R.Ae.S., President of the Institute of Navigation.

Opening the meeting the President said it was a very pleasant occasion for the Royal Aeronautical Society as it was their first joint meeting with the Institute of Navigation. He was glad to welcome his fellow-countryman and fellow-clansman, Sir Robert Watson-Watt. They hoped that they would have many other joint meetings of a similar kind.

He had much pleasure in introducing the lecturers, Dr. D. E. Adams, who was in charge of the Operational Instrument Division of the Instrument and Photographic Department at the Royal Aircraft Establishment, dealing with navigating and computing equipment, automatic pilots and gyroscopic, optical and general instruments; and Dr. A. M. Uttley, Assistant Superintendent of the Physics Department, Telecommunications Research Establishment, who was working on navigational equipment and digital electronic computing.

INTRODUCING the paper, Dr. Adams pointed out that the subject of Air Navigation was a vast one in which neither of them could claim to be expert in every branch. In fact, a large proportion of the time of the Institute of Navigation was devoted to the discussion of the various aspects of that subject. He and Dr. Uttley were taking the only course open to them in presenting the subject matter as a review, which at a joint meeting of that kind would not be out of place. Neither of them would claim to contribute very much in the way of original work of the kind which formed the basis of the more normal type of lecture, but he would attempt to summarise some of the factual data about the instruments of navigation, leaving to Dr. Uttley the latter part of the lecture in which to comment on the various aspects of presentation and use of the data and on the impact of equipment on aircraft design.

In his opinion an aircraft, from its earliest conception, should be designed with some specific role in mind.

They had brought some aircraft models to demonstrate the way in which efforts were being made to reduce the drag of an aeroplane and the weight of equipment.

1. INTRODUCTION

To the aircraft designer and contractor, those of us responsible for equipment may appear as arch-perpetrators of complex, bulky and weighty "gadgets," impossible to install and the source of all unsightly excrescences on the aircraft's skin.

Any aircraft, from its inception should be designed for some specific role, and its usefulness may well depend upon the availability or simultaneous development of equipment. In the civil field the safe,

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reliable, economic and speedy operation of a particular type may rest very largely on facilities which enable all-weather operation to be undertaken, including navigation, traffic control, and approach and landing facilities. Even more directly, military operations will be determined very largely by the instrument aids available.

If the operational role of an aircraft is to rest on instrument techniques, this should be recognised from the outset; as operating conditions become more exacting, the human sense organs and mental processes must be supplemented by other primary detectors and computing gear, so that the general problem of the accommodation of equipment becomes more pressing. As an example of an aircraft designed for a specific role one might quote the V-1; whether such weapons could be considered in any future war depends not only on the possibilities in respect of speed, height and range of a cheap expendable vehicle, but even more significantly on the possibilities of navigation and terminal guidance.

Our task will be to set out some of the principles, possibilities and limitations of *en-route* navigational systems. The problems of blind approach and landing were covered in 1946 by H. C. Pritchard[1] and will not be discussed; nor will consideration be given to the involved subject of traffic control, except in so far as it may be integrated with the main navigational requirements.

2. THE NAVIGATIONAL PROBLEM

2.1. General

The problem, basically, is that of planning a flight and knowing at any instant what measures are necessary to ensure the safe and expeditious conduct of the flight in accordance with this plan. Neglecting those circumstances in which the problem is one primarily of airmanship, the basic elements upon which navigation must be conducted are aircraft position co-ordinates and their time derivatives in the chosen system of reference.

2.2. Systems of reference

A complete specifying of the position or motion of an aircraft requires references to three co-ordinates in space and one in time. For flight in the atmosphere of the earth it is natural to identify one axis of reference with the local vertical. While the height co-ordinate is important for many purposes, the navigation of an aircraft in its ordained course will be treated here as, in the main, a horizontal two-dimensional problem.

The most generally applicable co-ordinates are the orthogonal ones based on the earth's axis—latitude and longitude—although in polar regions special measures are necessary to avoid rapid or discontinuous changes of longitude and azimuth. For local navigation it may be more logical to use a range and bearing system based on the destination point.

2.3. Meteorological aspects

An important factor in the general problem is the state of the air in which the flight is to take place. After the avoidance of dangerous icing conditions and heavy turbulence, the efficient conduct of a flight depends upon a knowledge of wind structure.

Careful planning is essential, especially if flights are to be made near maximum endurance; airline operators require statistics prepared for certain routes, heights and seasons of the year, while individual flights will be planned to make the best of the existing situation.

Forecasting is not perfect, and planning is not enough. The experienced navigator will have a clear appreciation of the general weather situation at all times, noting signs of frontal conditions, regularly checking wind velocity and making necessary modifications to the flight plan.

In high altitude flying it becomes especially important to observe wind velocities, which may reach very high values. A particular case worthy of note is the possibility of jet-streams[2]—fast-moving air streams occurring in the tropical air above the polar front at heights between 15,000 and 40,000 feet. These are of relatively narrow section (the wind speed may fall off 100 kts. with 100 miles horizontal displacement and 80 kts. in 12,000 feet of height), but may extend for hundreds of miles along the track of the wind. Both forecaster and navigator must be alive to this condition if these air streams are to be avoided—or utilised.

2.4. Requirements

2.4.1. *General*

The navigator must know his geographical co-ordinates of position and also his rate

vectors if he is to determine the plan of action and future schedule. Rates and position may be measured separately, but they are obviously inter-related by the processes of differentiation or continuous integration.

These quantities should be available, whatever the speed, height or course and whatever deviations have been necessary. For operation under difficult conditions it is a great advantage to have the integration of the speed vector carried out automatically. For some phases of the flight it is necessary to go further and to give the pilot executive signals enabling him to hold the aircraft to a prescribed flight path; this is required for bombing and for blind approach, but could be applied in principle to the whole flight.

Some form of navigational system must be operative at all stages and under all conditions of flight, and the complete service must demand as little as possible in weight, bulk, complexity, aircraft protuberances, servicing and skill in operation.

Increase in bad-weather flying and higher traffic densities combine to strengthen the demand for anti-collision equipment, whereby warning is given of the existence of obstacles in or near the path of the aircraft.

A fundamental service, which is partly navigational in its application, is two-way communication between aircraft and ground stations. For short-range work the problem is largely that of providing sufficient channels in conditions of high traffic density; this will involve frequencies higher than the present V.H.F. band. As an extension to this service it would be desirable to have a system of non-verbal signals as, for example, traffic control instructions which could not be misunderstood. Provision must also be made for long-range communication for the transmission of orders to change the plan of flight, or for meteorological or emergency messages.

2.4.2. *Civil requirements*

When ground co-operation is assured the technical problem of *en-route* navigation is very largely solved. Attention has recently been directed much more to the challenge which comes when operating large numbers of aircraft under bad weather conditions, a problem which reaches its most acute form in the areas around busy air terminals. In this sense it becomes essentially a problem of high-precision short-range traffic co-ordination.

This aspect will not be discussed here, but some of the desirable features are common with the general navigational system. For example, the equipment to be carried in the aircraft should be as simple as possible so that it may be universally fitted, the possibility of errors due to language difficulties on R.T. should be avoided and the efficient operation in all areas of a universally acceptable system should be ensured by international agreement. In this direction the International Civil Aviation Organisation has already done much good work, although the ideal state is still far distant.

2.4.3. *Military requirements*

So far from receiving assistance from the ground in wartime, the navigator over enemy territory will have to face the most persistent efforts to deprive him of all help and perhaps to mislead him with false information. Thus, the first essential of any aid for bomber aircraft is availability—that is a self-contained system which, if it refers to external objects at all, should use only such as cannot readily be camouflaged. Presentation should be such that attempts to deceive are detectable.

Accuracy may be a primary requirement if a high concentration of aircraft is to be used, each being independently navigated, although really high precision is normally demanded only for the attack and for the approach to land at base.

Special problems arise for fighter aircraft, which may not be susceptible to individual control from the ground in certain circumstances. Here the problem is one of simple and rapid means of combining fix information, position reporting and computation to show the action necessary to bring the target within range of the interception equipment. Since the endurance of some types of fighter aircraft will be quite short, there is a need for means of bringing them directly to base and into the landing approach without delay, a tricky problem if large numbers are involved and visibility is bad.

3. NAVIGATIONAL SYSTEMS

3.1. General

Consider first the problem of producing in an aircraft two quantities defining in some way the aircraft's position relative to the

earth's surface. It is important to distinguish between an actual co-ordinate θ_i (say) from the displayed co-ordinate, θ_o (say), which has been obtained by measurement and calculation; their difference $\theta_o - \theta_i = \theta$ is the error of the system. θ_i is the input, master, or controlling quantity. θ_o is the output, slave, or controlled quantity. We are borrowing here from the language of control engineering.

This task of controlling one quantity by another may be achieved in two distinct ways. The first and simplest method is exemplified by a water tap or the accelerator pedal of a car. The controlling quantity, calibrated perhaps, is set at a given value, and it is hoped that the controlled quantity, water flow or car speed, for example, will attain a desired value. The system is shown diagrammatically in Fig. 1. The arrows show the direction of control or sequence of cause and effect. Should the control mechanism change its characteristics the controlled quantity will be in error, and the system will make no automatic correction.

If, however, the controlled or output quantity be measured, and compared with the controlling or input quantity, then their difference may be applied to the control mechanism in such a sense as to minimise error. Fig. 2 shows the sequence of control which clearly forms a closed loop.

The most significant feature of a closed loop control system is that the control mechanism does not need to be calibrated, it may even vary within considerable limits without affecting the overall accuracy of the control system.

Navigation by open loop control consists in the use of calibrated instruments measuring speed and direction and in hoping that their integrated outputs indicate aircraft position. Change in characteristics of the instruments results in errors about which no action is taken.

Theoretically, given sufficiently good instruments and maps it should be possible to drive a car in this way. Practically, because the road is sufficiently wide at sea and in the air the method can then be employed. It is called Dead Reckoning Navigation. The motorist prefers to use the method of visual fixes relative to the kerb. He measures the error θ of Fig. 2 which is applied to the control mechanism, the steering wheel. So too in the air the method of fixes, the closed loop method, is likely always to be required. However, the increasing accuracy and stability of speed and direction instruments gives rise to a school of thought that believes in D.R. alone for *en-route* navigation.

In the open loop or D.R. system of Fig. 1 the controlling quantity will be rates, for example, speeds E/W or N/S. The controlling mechanism can be the navigator himself who computes θ_o the calculated position. This is the simplest system—Manual D.R. As a next step D.R. may be made automatic.

In the closed loop or fix system of Fig. 2 the whole process can be manual. The control mechanism again represents a running D.R. computation affected by speeds E/W and N/S; but by comparing a manual fix θ_i with a calculated position θ_o given by D.R. a modification (feedback control or reset) is applied to the rates fed into the D.R. system. Again the D.R. can be automatic with manual reset; as a further step the act of obtaining a new fix can automatically modify the rates fed to the D.R. computer.

Where tactical freedom is important, as in most military operations, the D.R. position should be computed continuously and automatically. Taking automaticity one stage further, it is possible to compare the present position with a future desired position and to compute quantities which may be displayed to the pilot as instructions for directing the flight path of the aircraft and as time, or distance, to go. The requirement for this type of presentation is more pressing for instrument approach or instrument bombing than for *en-route* navigation.

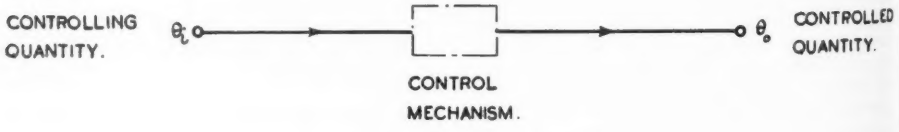


Fig. 1.
Open loop control.

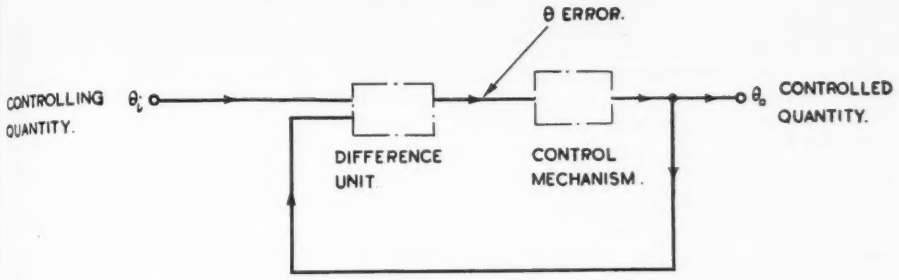


Fig. 2.
Closed loop control.

3.2. Rate determination

3.2.1. *General*

In an aircraft having no kind of contact with the ground, it is practicable only to determine its motion relative to the air mass in which it is flying. Geographical position can be deduced only by the application of a forecast wind vector. The elimination of inevitable forecast wind errors is made possible only by the observation of ground positions or ground speeds and drifts during the flight. Even so, it is convenient, in the general case, to base the running D.R. computations on separately identified air speed and wind vectors.

3.2.2. *True air speed*

Although some difficulties arise in its application, no other principle has supplanted the pressure-head method of measuring air speed. For true air speed it is necessary to measure pitot pressure, static pressure and temperature. By a simple manual computation, true air speed may be derived from the readings of the air speed indicator, altimeter and thermometer, but if freedom of manœuvre is important and if full use is to be made of automatic dead reckoning equipment, true air speed should be continuously available, for which purpose two principles have been employed.

In the first, capsule displacements due to the three basic quantities are combined through light mechanical lever movements to give a dial presentation of true air speed. For certain more approximate purposes the thermometer may be eliminated, an average atmospheric temperature distribution being assumed. For automatic equipment a servo-driven pick-off must be provided. This system presents a very tricky tuning problem in manufacture. It has found more favour in the U.S.A. than in Great Britain.

A second principle has been adopted in the air mileage unit which has been found more convenient in Great Britain as a primary element of automatic dead reckoning equipment. In its simplest form, this instrument uses the principle of balancing pitot pressure against the peripheral pressure in a centrifugal fan with static pressure at its centre. Fan speed can be made very closely proportional to true air speed and independent of temperature and static pressure. An installation problem arises in that the fan temperature must be kept as nearly as possible at outside air temperature.

Improvements in instruments may be possible in the determination of true air speed, but the more basic requirement is that the three fundamental quantities shall be available in high speed aircraft. The most difficult to provide is static pressure, which is required also for pressure altimeters. In the past, static vents (flush with the aircraft skin) have presented not only a simpler de-icing problem but, in general, have provided a smaller and more consistent position error than the combined pitot-static head in Service aircraft. The siting of static vents can only be accomplished by flight tests and positioning might be very critical in new high speed machines. In view of past experiences it seems reasonable to examine the possibilities of static vents in new aircraft as they become available, besides making provision for a combined pitot-static head in a position well outboard and well ahead of the leading edge of the wing.

3.2.3. *Heading*

For purposes other than total air mileage measurement, true air speed, for navigational

purposes, must be supplemented by a knowledge of the direction of the aircraft's path relative to the air—its fore and aft direction if sideslip is ignored.

Some property of the earth itself might be expected to give the most direct datum against which to measure heading in relation to rotating earth's axis. Earth's rotation cannot be used directly for controlling a gyro element as for ships' gyrocompasses, since aircraft motion may nullify or reverse the directing force.

The only other natural property usefully employed to date is the magnetic field of the earth. In order to avoid well-known defects of the liquid bowl compass the most recent systems use a gyroscopic direction indicator monitored at a fairly low rate from a magnetic element sited in a remote and magnetically clean part of the aircraft. While the probable error of such an instrument may be kept within half a degree under laboratory conditions, the value in straight and level flight is unlikely to be better than one degree and appreciably worse under conditions of accelerated flight.

The magnetic datum itself is uncertain by a half degree or so over well-surveyed territory and by much more in some parts of the world. Uncertainties arise from secular changes, diurnal and seasonal changes and magnetic storms, apart from the inaccuracies of plotting isogonal data.

The overall operational accuracy of the compass is likely to be rather poorer than that of the measurement of true air speed; in areas where no major uncertainty in the magnetic datum exists the total probable vector error in air position will amount to about two per cent. of the air distance travelled.

In cases where drift and ground speed can be more accurately determined than true air speed, a more accurate azimuth is required if full use is to be made of the available data. For this, reference must be made to directions fixed in space—a free gyroscope or a celestial body. In neither case is there a quick or easy answer, although both show promise. Astro references have long been used for compass checking in flight, but continuous operation demands automatic alignment, a good vertical reference and a knowledge at all times of geographical position.

For flights of any appreciable duration, an unmonitored direction indicator must be something of the order of a hundred times better in respect of random wander than existing aircraft instruments. Using a horizontal axis gyroscope it is necessary to correct for earth's rotation and the aircraft's motion, and the indicator itself would require stabilisation to avoid errors in and after turning flight.

3.2.4. *Drift and ground speed*

D.R. navigation can be corrected only by rates measured with reference to the surface of the earth. If the ground can be seen from the aircraft a visual device may be used to determine drift angle and, if height above the surface is accurately known, ground speed. For accurate observations such a device must be stabilised or the readings averaged. Drift is the easier quantity to determine, and if measured on two or more headings the wind may be deduced and combined with T.A.S. and heading to give track and ground speed. For high flying aircraft the ground is visible only on a small percentage of occasions and the method of multiple drifts now finds little application.

An interesting development of geostrophic wind theory allows the total lateral component of wind to be determined from barometric and radio height measurements. The main virtue of the method is that the beam component of wind is integrated; however much it may vary from point to point during the flight, the total beam effect is expressed as a constant (involving mean latitude) times change in height of a given pressure surface divided by true air speed. On this basis it is very simple to plan a flight to be made on a single heading, knowing only the difference in height of the pressure surface at the flight level between home and destination. The theory can only be applied safely in middle latitudes and accurate determination of height above M.S.L. is practicable only over extensive areas of water.

The complete ground movement vector may be determined without visual contact with the ground if H_2S is carried. In this radar system a map of the surrounding terrain is presented to the navigator in the aircraft. From the drift of this picture on the cathode ray tube, or by various methods of tracking a specific response, the components of ground speed may be observed without the necessity of identifying the

response used. If the presentation is north-stabilised from the compass the track angle can be read directly.

If a drift and ground speed service is available there is no need to measure true air speed if the object is simply to make a successful "track-crawl." Moreover, true air speed may be deduced if drift and ground speed are measured on two or more headings. If a complete picture of the situation is required, however, so that computations may be made in advance for a new heading, and if the integrated air-mileage is required, it is necessary to separate the air speed and wind components. For this purpose it is most convenient to have true air speed determined directly. Unless the drift and ground speed measurement is continuous it is again necessary to have air speed in order that changes in this quantity may be continuously accommodated in the D.R. computation. Corrections to the D.R. rates from ground observations are then applied directly as corrections to the wind vector.

The principle of radio Doppler speed measurement has been quite widely used for observation from ground stations of projectiles in flight, and could obviously be applied to the monitoring of airborne D.R. equipment in the early stages of flight.

Theoretically it should be possible to navigate by means of accelerometers alone. The main reason why this is not practicable is that the accelerometer will measure a large unwanted term—due to the earth's gravitational field—unless it is always mounted on a truly horizontal platform; one degree of error here will produce a spurious error of about half a foot per second per second which will provide a velocity error of about 600 m.p.h. in one hour. Moreover the range of sensitivity would have to be extremely wide to cover all conditions of flight.

3.3. Non-radio position fixing

3.3.1. *Visual*

An identifiable landmark may be looked upon as providing the most direct aid to navigation, but this facility is of limited application in view of the large percentage of flying time spent over the sea, over featureless land, in conditions of cloud or poor visibility, or at night. Even so, special measures were taken during wartime operations to make visual aids available to aircraft not equipped to conduct precision navigation without them; for example, pathfinder route and target marking, aerial lighthouses, searchlight-assisted homing, and gunfire marking.

When visual sighting is possible, great care must be taken with high speed, high altitude aircraft in both sighting and timing; a good vertical reference is required for precision fixing or for photographic recording.

3.3.2. *Astro*

At a height of, say, 40,000 feet, the risk of cloud interfering with astro observations is remote and it might be profitable to take advantage of the features of universal coverage by night without ground assistance, immunity from enemy interference and uniform accuracy which astro offers, the sighting instrument being neither bulky nor difficult to maintain. As generally practised, however, a number of factors contribute to discourage the use of astro if radio aids are available; accurate flying is required while sighting and it may take as long as fifteen minutes to obtain a reliable fix. In high-speed aircraft the probable error will be at least 10 miles, even in smooth air, and the normal astrodome is an embarrassment to the aircraft designer. The full service is available normally only by night.

A current development—the periscopic sextant—eliminates the need for a large dome, a small protuberance only being presented while actually sighting (Fig. 3). Some measure of precomputation for a planned flight would save appreciable time in the process of position fixing. Averaging over a period of two minutes or so must still be used to arrive at a reliable altitude; a stabilised reference, accurate and reliable enough to warrant a single-shot sextant, is still some way off.

Work proceeds on this problem of the stabilisation of equipment to a true vertical, and when three or four minutes of arc can be obtained in steady flight it will be possible to re-examine the old ideas on two-star sextants which give latitude and longitude directly. So far, these devices have been impracticable to handle in the air, and even with a stabilised platform it may be necessary to simplify the procedure by using Polaris always as one of the stars.

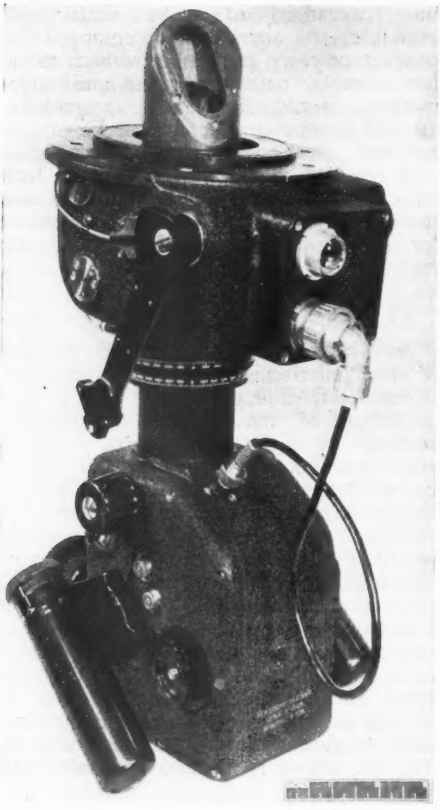


Fig. 3.

At great heights, given a stabilised platform and using Polaris, it is interesting to re-examine also the feasibility of astro by day. It is estimated that a telescope would be required having an objective of about $2\frac{1}{2}$ inches diameter, a magnification of about 12, the field of view being about 3° maximum. The installation of a device of these dimensions might be difficult, and the effects of vibration could only be determined by flight experiments.

3.3.3. *Gyroscopes*

Since the directional rigidity of the axis of a perfect gyroscope is equivalent to a star reference, two such gyroscopes could be used instead of stars for position-fixing. Since one minute of arc displacement of the gyro axis would be equivalent to one nautical mile position error, the application of gyros to navigation over any appreciable length of time can be considered seriously only when they can be produced with random wander of the order of one minute per hour. Gyroscopes may be used in a variety of ways for rate and position determination, but the basic requirement for lower random wander-rates is inherent in all. The normal dash-board gyro may have a wander rate of some tens of degrees per hour in flight; the degree of improvement required demands that new techniques be applied for the elimination of unwanted friction and torques.

3.4. RADIO FIXING

3.4.1. *Search radar*

The aircraft navigator is frequently denied visual guidance from ground features by the incidence of rain, cloud or haze. Infra-red wavelengths offer no advantage, except for photography through fine-particle haze. Radio frequencies give excellent penetration, but lose angular resolution in proportion to wavelength. For many purposes three centimetre radiation has been found to give a good compromise between penetration and resolution.

It is possible for the aircraft to transmit radiation at such wavelengths, to receive the reflected echoes from natural ground features and to present the radar picture of the ground in the form of a "map" on a C.R.O., such a presentation being referred to as a Plan Position Indicator (P.P.I.).

Such pictures may be difficult to interpret; not only does the representation differ for different surface conditions—dry or wet—but also when viewed from different directions. This is true of visual also, but in the process of evolving the visual sense we have learned to interpret impressions under all normal conditions; the lower resolution at radio frequencies hinders this ability for a radar picture, although the importance of familiarity with the vagaries of equipment and practice in interpretation cannot be over-emphasised. In spite of these limitations there are usually (over land) sufficient unmistakable objects available—lakes, rivers, isolated towns—to enable navigation to be conducted.

The most direct application of this "radar eye" is in the avoidance of obstacles (aircraft, high ground or storms) or in navigation based on map-reading. The

former role has been adopted extensively for marine use; in aviation more use has been made of the navigation and bombing functions. The military value is obvious in that ground co-operation is not required and "spoofing" is not easy. In addition to ground returns it is possible to utilise responder beacons to facilitate navigation.

The characteristic of optical sighting is high angular resolution, while the feature of radar is accuracy of range; it is important to realise that if full use is to be made of this type of radar for precise position or rate determinations, ranges rather than bearings should be relied upon. Because of aspect changes, and so forth, high precision could be achieved only after careful photographic and radar survey or reconnaissance.

Before such equipment can come into common use for civil aircraft something much simpler than the military versions must be developed; normally the need in the civil field is for a forward-looking system only.

Search radar may be used not only in the aircraft, but also on the ground for monitoring and control purposes. Schemes have been proposed in which ground radar information is transferred by television or other means to the aircraft.

3.4.2. *Radar ranging*

If it is assumed that ground stations or responders may be used, then the full accuracy of radar ranging may be exploited. The most direct scheme would be to measure distances from two ground references, fixing the aircraft on the intersection of two circles. This may be achieved either by having the range measuring equipment on the ground (with responders in the aircraft for any long distance application) or else in the aircraft, using only responders at the fixed ground positions.

In the former case high accuracy is possible, but handling capacity is very low and reliable communications with the aircraft must be maintained. "Oboe" was based on this principle. The latter system forms the basis of G-H and Shoran; the handling capacity of the responders is relatively high, but the aircraft equipment is more complex and transmitters are required in the aircraft. In both cases the accuracy is higher than is necessary for navigational purposes, but a useful peacetime application has been found in survey flying.

High precision systems of this nature are operated in the V.H.F. or U.H.F. bands and the working range is not much greater than that set by the optical path.

Under the general name "Rebecca," range measuring systems have been in use for some time as homing aids for aircraft and several new range measuring sets are under development. The main feature of the new development is the direct presentation of range on a dial without the necessity for reading a cathode ray tube. This is designed to simplify the adjustment of the time of arrival at an airport and the execution of traffic control patterns. These systems give service up to the optical distance, or about 100 miles, whichever is the lesser, with an accuracy of about 2 per cent. to 5 per cent. of range. It will be necessary, perhaps, to demand accuracy of about $\frac{1}{2}$ per cent. of range for the final stages of navigation, but this is not difficult to meet in principle. The ground beacons are limited in capacity to handling between 50 and 100 aircraft simultaneously.

3.4.3. *Time-difference methods*

A second group of systems is based upon range or time difference measurements. Ground station *A* emits a pulse and, by land line or radio link of accurately known time delay, causes two slave ground stations, *B* and *C*, to emit pulses. A receiver in the aircraft receives all three pulses. The time difference in the arrival of *A* and *B* pulses determines a hyperbolic position line, while a second position line using *A* and *C* pulses serves to give a positive fix. Gee and Loran are based on this principle, the former for medium and the latter for long-range operation.

The time differences are observed on a cathode ray oscilloscope, manual alignment being required. This seeming disadvantage could be removed by the development of locked-strobe methods, the co-ordinate position being automatically displayed. For military purposes, however, when interference may be deliberate, the visual display is to be preferred.

The Gee system works between 20 and 80 Mc/s. and gives roughly a range of 350 miles at 15,000 feet and 200 miles at 5,000 feet. These ranges are obtainable in all weathers, since at these high frequencies natural static interference is negligible. At maximum range the accuracy is adequate—

within one mile or so—for normal *en-route* navigation; a few hundred yards position line error is possible at short ranges.

Standard Loran works at a higher wavelength and uses sky wave returns for ranges up to 1,200 miles by night. Ninety-five per cent. of readings will lie within one per cent. of the range in the central areas of coverage, although appreciably higher accuracy is achieved when the ground wave is used. The presence of both ground and sky waves demands some skill in selecting the required signal, but this type of presentation permits working through appreciable atmospheric noise.

Loran may be used in the L.F. band to give long-range cover by day and night at all operating heights. Maximum range will be determined largely by the noise level and may be expected to vary between about 1,200 and 2,500 miles. If a long enough base line for the stations can be accommodated the accuracy will be similar to that given by standard Loran. It has been estimated that about 20 Loran chains would give complete cover for the world's air routes.

These systems found great application in wartime and, by rationalising the design of common equipment, could be combined to give a universal service for peacetime operation. The disadvantage of non-automatic operation is offset by the greater certainty of the information visually displayed. Some difficulty might be experienced in the integration of the Gee system with traffic control and landing aids, as the computation of straight line courses is somewhat complex and computers require resetting on passing from one chain to another.

In this same class, although operating on a different principle, is the Decca Navigator. A simple ground chain consists of three stations as in Gee, sited about 60 miles apart and radiating phase-locked unmodulated C.W. signals. Since a typical aerial spacing is a hundred wavelengths of the phase comparison frequency, there will be about 200 lanes of 360° electrical phase change on either side of the base lines, each lane being about one degree in width.

The aircraft receiver picks up the three stations and after converting their signals to a common frequency it compares their phases and displays the result on meters. These meters read directly in lanes and fractions of a lane. As the aircraft moves the meters will indicate its movement continuously with respect to a hyperbolic lattice over-printed on a map. In order that Decca may provide a more positive fixing system a scheme of lane identification has been introduced; ambiguities are reduced to sectors of about 15°, so that aircraft entering the system from outside may begin from a definite position, so long as normal navigational techniques have been used up to that time.

This phase comparison system is capable of a very high accuracy—1/18° near the normal to the base line—and, the wavelength being in the L.F. band, operation is possible at all heights up to the maximum range. By night, operation beyond 200 miles is likely to be uncertain because of the arrival of signals by different paths. It is possible to use the system up to 1,000 miles by day. The receiver employs a narrow band-width and so is well protected against static; however, it must be remembered that the frequency—about 100 Kc/s.—is particularly liable to precipitation static and this may well prove troublesome at times for aircraft operations.

The Decca system has been widely used for shipping operating within its coverage; for aircraft, its role—in preference to other systems such as Gee—would appear to be for special operations at low altitudes, where the highest accuracy is required and where the simplest presentation is essential.

3.4.4. *Radial position lines*

Apart from normal communications, the earliest application of radio to navigation was in "direction finding." Radio direction finders comprise a directional aerial system which may be mounted either on an aircraft or at a ground station. An aircraft may take bearings on a ground transmitting station or, conversely, the aircraft may transmit a signal so that its bearing can be measured by a ground station and relayed to the aircraft by a communication channel. Such bearings may be used for homing or as position lines for general navigation. By combining bearings from two or more ground stations at a plotting centre, a fix may be given to an aircraft by a ground-based D.F. organisation.

An M.F. or H.F./D.F. station uses a directional aerial system which must be situated on flat ground, free from nearby

obstructions. The station must be manned by a skilled operator who takes bearings on short morse transmissions from the aircraft, operating on one aircraft only at a time.

The accuracy of the bearings is a complicated function of many variables, but taking average conditions, a good site and the best type of aerial, such D.F. stations provide a short range navigation aid with a probable error of one to $1\frac{1}{2}$ degrees, and a medium and long-range aid with probable error of $1\frac{1}{2}$ to 3 degrees. Such systems are subject also to static interference, especially in tropical areas. M.F. and H.F. transmissions may be jammed by distant transmitters, and sky waves may disclose aircraft positions to enemy stations at long ranges.

Increasing use is being made of V.H.F./D.F., bearings being taken on short voice transmissions from the aircraft. Since the range is limited by the optical horizon, this is useful only as a short-range homing or fixing system, but reliable service is given under all weather conditions. A flat site is again required and the probable error is of the order of $1\frac{1}{2}°$.

An aircraft D.F. set or "radio compass" consists of a receiver, directional loop aerial and an aural or visual bearing indicator, from which may be determined the bearings of M.F. beacons or broadcast stations. There is no need for transmissions from the aircraft.

The maximum range of a radio compass depends not only on the particular installation but on the power of the ground station, the terrain, the time and season and the prevailing static. For homing purposes, the useful range of a radio compass to a one kw. M.F. beacon is about 200 miles over land and rather more over the sea. Noise may be such as to reduce the range below 50 miles.

The radio compass must be used in the region where the ground wave predominates, the loop aerial being subject to polarisation errors on sky waves. Thus, ranges of 600 miles are possible by day and about 100 miles by night.

The probable error of a bearing is likely to be between 3° and 5°, so that the radio compass is used mainly for homing and for rough checks of dead-reckoning.

A fixed loop is sometimes used to permit homing to a V.H.F. transmitter, and directional aerials are used in conjunction with radar distance measuring equipment (Rebecca) to enable the aircraft to home to the ground beacon.

By suitably designing the transmitter aerial array it is possible to radiate particular field patterns; these may be interpreted in an aircraft as indications of the bearing of the transmitter. The simplest application of this principle is the radio range, used very widely in the U.S.A. Four fixed tracks radiate from the station and with very simple equipment in the aircraft, it is possible to fly along either of the tracks, which are marked on the aviation chart.

Most fixed-track ranges work in the M.F. band and the maximum useful coverage varies from several hundred miles to zero, according to conditions. It is essential to choose a good flat site for the station, but other terrain features may still cause large local anomalies. By using V.H.F. transmissions, fixed-track ranges have been made to work reliably under all atmospheric conditions up to optical distances, but the requirement for freedom from obstruction near the transmitter is even more stringent than for M.F. stations.

Fixed-track ranges can be used by any number of aircraft simultaneously, but are not suited to the safe control of traffic at high density. For this reason considerable thought and effort has been expended on omni-directional ranges—which provide bearing information to aircraft at any point around the station.

The simplest application of this principle is the type of range in which the pilot must listen to a coded signal or voice transmission in order to estimate his bearing. The purpose of such systems was to provide a low accuracy ($\pm 5°$) homing aid, suitable for fighter aircraft.

More elaborate systems have been produced to display bearing directly on a meter in the aircraft. The most advanced example is the C.A.A., V.H.F. omni-range (British O.R.B.). The ground equipment consists of a transmitter and aerial system which provides a rotating field pattern. The aircraft carries a V.H.F. receiver, an azimuth selector and a centre-zero meter. By comparing the phase of the rotating radiation pattern with that of a reference signal radiated omni-directionally, the bearing of the aircraft from the beacon is determined. The principal limitation of this range appears to be its dependence on a

good site; figures to date suggest that the probable error of a good installation is likely to be 2° in azimuth. Some hundreds of these beacons are scheduled for installation in the U.S.A. as part of the traffic control programme.

A pulsed omni-range has been demonstrated experimentally, the purpose being to provide a system free from site errors. If the transmitters of a Gee chain are brought in close together the hyperbolæ become very nearly straight radial lines. Very high precision is necessary in the timing circuits of the ground station and the airborne equipment, too, is complex and the idea has not been pursued.

Attempts have also been made to evolve practical systems of precise azimuth indication based upon the use of a narrow rotating beam and pulse transmissions.

Radial position lines at long range may be provided by Consol—the British equivalent of a German navigation system formerly known as Sonne. A multi-lobe polar diagram, produced by a three-aerial transmitter is coded with dots and dashes and automatically swung in azimuth. Having resolved the ambiguities of the pattern by a rough D.F. loop-bearing the navigator can determine an accurate bearing by counting the coded signal.

The frequencies chosen for British stations lie in the band 263 and 415 c.p.s. and only a normal communications receiver is required in the aircraft. The system has the disadvantage that it is open to interference by static or other transmissions and, because the time of observation is half or one minute, the count is liable to be upset. It is very vulnerable if considered as a military aid.

The accuracy of Consol is quite high under the best conditions, *e.g.* 1/5 of a degree, but in the regions where, at night, sky wave and ground wave interfere, the probable error may rise to several degrees. The maximum range will depend upon the noise level; 1,500 miles over the sea and 1,000 miles over land have been obtained from European stations, but much lower useful ranges are to be expected in tropical regions.

Experiments have been made with long-range systems designed to give a direct display of bearing in the aircraft. In the P.O.P.I. system, for example, radiation from a multi-aerial beacon allows the bearing to be determined by phase discrimination in the aircraft receiver. Accuracy will normally be of the order of 2°, but may be expected to deteriorate when sky wave and ground wave interfere—between 100 and 500 miles at night.

Suggestions have also been made for L.F. omni-directional beacons with maximum ranges of about a thousand miles, using a rotating modulation field and a reference modulation as in the V.H.F. omni-range.

4. PRESENTATION AND COMPUTATION

The primary task of the navigator is to plan the future progress of a flight on the basis of present and past information. Because of the uncertainty in forecasting winds, continuous checks must be made and discrimination must be exercised if the best use is to be made of available position and rate measurements. For this purpose it is necessary for the navigator to have the D.R. position, means for position fixing, a clock, chart and any relevant route data. The combination of rate vectors and the time-integration required for D.R. navigation is conveniently performed by instruments, this being essential when tactical freedom is required, with many changes of heading, air speed and height.

It is doubtful if instrumentation beyond this stage is warranted except in those situations where immediate action is required of the pilot in order to follow very closely a prescribed path—an automatic bombing run or rigidly defined traffic lane, for example, when he should be given a steering indicator and, in some cases, a distance or time-to-go indicator. For bombing use the aiming point will itself be used for visual or blind control of the approach; for the traffic lane the simplest solution appears to be the range and bearing system adopted by the U.S.A.

A number of course-line computors have been designed to show along-track and off-track errors from range and bearing data, when flying to a point some distance from the site of the station. The destination can be defined by two co-ordinates and the approach track by one angle, so three settings are required for any one track line. This complicates the procedure considerably if the tracks are not continuous straight lines between the two points. The inherent accuracies of the present-day range and

bearing measurements and of the computation, demand that if parallel tracks are to be flown they must be spaced by several miles. In one type of computor, for example, ten miles has been suggested as a safe spacing[3].

In view of the difficulties associated with deviations from the straight line, it is suggested that the simplest solution to the problem, where continuous fixing is available, is a direct map presentation. Using the distance-bearing system this is very simple; with hyperbolic co-ordinate systems such as Decca, lattice readings may be plotted as rectangular co-ordinates on a suitable map projection to simplify automatic presentation[4].

Reverting to the more general case, a navigator should have his D.R. position, wind velocity and true air speed to enable him to compute any new heading, and controls with which he may adjust his position and wind velocity in accordance with fixing information. If a secondary computation of pilot's steering information and time-to-go is automatically provided the navigator need have only present position and wind velocity displayed, although track and ground speed provide useful snap-check indications of progress.

An interesting development in pilot presentation is the Sperry Zero Reader which greatly simplifies manual instrument flying, especially in the critical approach phase. In principle, data from the primary flying and navigation instruments and from conventional radio systems may be combined with the selected plan of flight to provide signals indicating the manœuvre required to achieve the required flight path. Rate terms are included, exactly as if the signals were to be fed to an automatic pilot; it is required only to maintain zero coincidence on cross-pointers indicating pitch and azimuth control in order to achieve and to hold the selected flight path, the degree of correction being automatically that required for rapid and smooth correction of errors.

For a given degree of complexity in the requirements, the weight, accuracy and reliability of airborne computors is governed almost entirely by the availability of suitable electro-mechanical and electronic components. The reliability of radio valves was discussed at a previous meeting of the Society[5]. There is a wide and insufficiently covered field for small and reliable precision components such as potentiometers, selsyns, electro-mechanical integrating devices and low-inertia servo motors.

Availability of components also determines to some extent the choice of a system —mechanical, electro-mechanical (A.C. or D.C.), electrical or electronic. Electro-mechanical analogue computing provides the most flexible system for the continuous operations required in navigation; for the simple resolution and integration required in the estimation of D.R. position without rate determination, a mechanical system based on wheel and disc gears has been applied in the automatic dead-reckoning equipment used by the R.A.F. and has much to recommend it.

5. THE INFLUENCE OF NAVIGATIONAL EQUIPMENT ON AIRCRAFT DESIGN

5.1. Weight

Appreciable strides have been made in the weight-saving aspects of design. In electronic equipment transformer iron has been a principal offender. The weight penalty has been reduced by the adoption of higher frequencies in power packs and by the introduction of new magnetic materials. There has been a general move to miniaturise radio components with consequent saving in bulk and weight (Fig. 4).

On the mechanical side, the more liberal use of magnesium and the strict application of weight-saving principles—even at the expense of more costly machining operations—can lead to improvements which might be illustrated by the Air Position Indicator Mark 1A produced in wartime and now redesigned to reduce its weight from 21 lb. to about 14 lb.

Two further factors might be mentioned as adversely affecting overall weight—pressurisation for high-voltage equipment used at great heights (and to a lesser extent sealed units to operate under all climatic conditions) and heavier electrical power demands for more complex units.

5.2. Drag

In high-performance aircraft drag matters more than weight and it is essential to avoid all protuberances and breaks in the aerodynamically desirable contour.

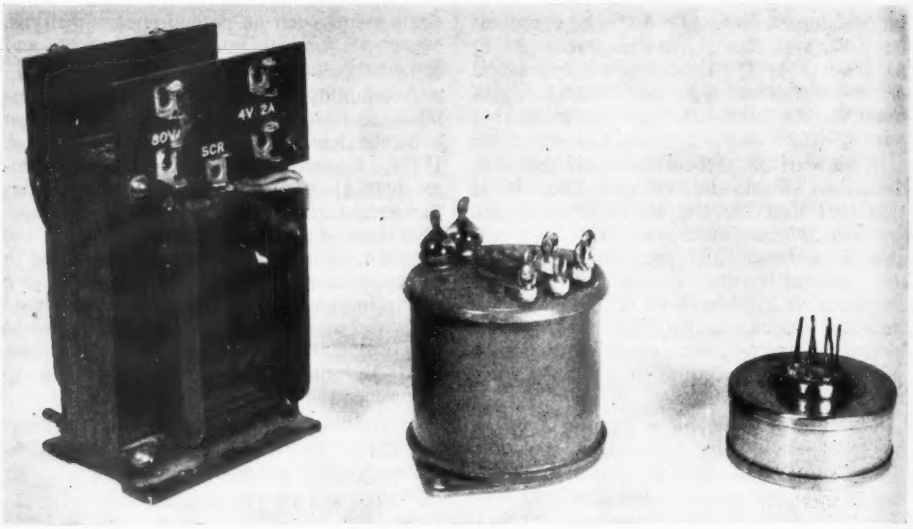


Fig. 4.

5.2.1. *Visual stations*

The most conspicuous bulge on the top of the aircraft has been the astro-dome—a hemisphere of 22 inches diameter. Structurally, as well as aerodynamically, this feature is an embarrassment in pressurised high speed aircraft; it can be eliminated by the use of a periscopic sextant. A British version is now undergoing trials and has already been illustrated (Fig. 3). The protuberance here amounts to less than three inches in maximum height and this is present only during the time of sighting.

Ground observations may be needed for map reading, fixing or drift and ground-speed determination. Modern drift meters are periscopic and present no appreciable problem, except for suitable installation positions. Bombsights have often been used for navigational purposes (drift, fixing, closed-circuit wind-finding, and so on).

5.2.2. *Radio aerials*

Aerials used on aircraft may be divided into three classes according to wavelength:

(*a*) Wavelengths down to three metres; or briefly dekametres.

(*b*) Three metres to fifteen centimetres, or briefly metres.

(*c*) Fifteen centimetres to 1.5 centimetres, or briefly centimetres.

Dekametres

In the past, aerials for these wavelengths have been made in the form of long wires either trailing free or running aft to the stabiliser, but drag now rules them out of court. The fundamental requirement is to provide an object of dimensions about a quarter of the wavelength which shall possess capacity with respect to the aircraft fuselage. At least two solutions to the problem exist. In the first method some protruding object can serve as an aerial; a single main wing can be used, or half a tail-plane or the stabiliser. The aerofoil can be stimulated or fed either at the centre or at the tip, by an insulated feeder (*see* Fig. 9). Alternatively, the member can be coupled inductively by a coil near the root and insulated from it[4].

By the second method one of the flying surfaces is wholly isolated electrically from the fuselage by a dielectric section. Less drastically the flying surface can form an aerial if only its tip is so isolated; in both cases the feed is across the dielectric section.

Metres

Here the slot aerial produces an almost perfect solution. An aerial produces a radiation pattern in a similar way that an optical slit produces a diffraction pattern.

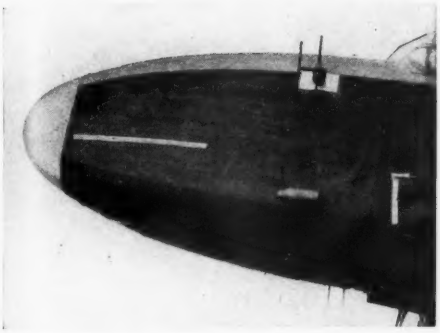


Fig. 5.

Clearly an infinite conducting sheet produces no pattern, however stimulated; nor does an infinite aperture optical slit. It follows that the difference between these two cases must produce a field pattern. In the electromagnetic case the difference between an aerial and an infinite sheet is a hole in the sheet. In the optical case the difference between a slit and an infinite aperture is an obstructing bar. The fact that the complementary objects produce complementary radiation patterns is known as Babinet's Principle. The practical requirement is for a conducting sheet, the surface of the aircraft, and a slot in it. The principal difficulty likely to arise is that slot aerials may tend to foul important members of the airframe (*see* Figs. 5, 6, 7 and 8).

Centimetres

Here the fundamental requirement is for a paraboloidal mirror, often with rectangular boundaries to economise on depth.

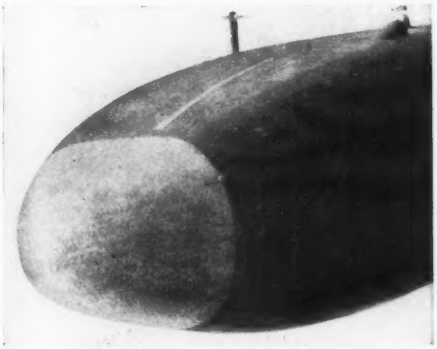


Fig. 6.

For navigational purposes the aerial must be able to radiate freely in the horizontal direction and downwards at any angle including the vertical. The first solution was a hemispherical blister on the under surface of the fuselage. For seeing in all directions two such blisters would be fitted, one above and one below, or perhaps one for the port hemisphere and one for the starboard hemisphere. This is the solution adopted by birds. The pigeon's head is a good example.

High speed flight just forces these two view points, or radar eyes, to be at the nose and tail. Except for the case of being attacked by a faster aircraft the tail aerial sees the past and the nose aerial sees the future. For H_2S navigation the aerial has thus been forced into the nose with consequent loss of vision aft.

In animal evolution it was the decision of the earthworm to be unidirectional in its movement that caused new sensations to arrive at one particular end; this led to the accumulation at this front end of sense organs and of a brain to assess them—hence the snake. Hence also, the arrival at one end of an aircraft of pilot, aerial, drift sight, gun-sight and bombsight, in a state of competing congestion. The problem has to be solved—not avoided.

Designers have tried hard to produce dragless designs. They have succeeded, although in the process they have raised problems of construction which can only be solved cleanly while the aircraft is in the design state. Given this condition it is clearly possible to design an airframe so that slot aerials do not foul its members. Similarly it should be possible to isolate small parts by means of dielectric sections, *e.g.* wing tips, complete fins, and tailplanes, rudders and elevators. This is more difficult than the provision of slots and it may be that metre wavelengths will be used more and more in favour of dekametres.

5.3. Internal Layout

Under this heading may be included:—

(*a*) Equipment that does not have to be touched in flight.
(*b*) Equipment that has to be manipulated.
(*c*) Instruments that have to be seen.

Equipment not touched in flight includes measuring instruments, such as air mileage units, electronic amplifiers, modulators, transmitters and receivers, master compass

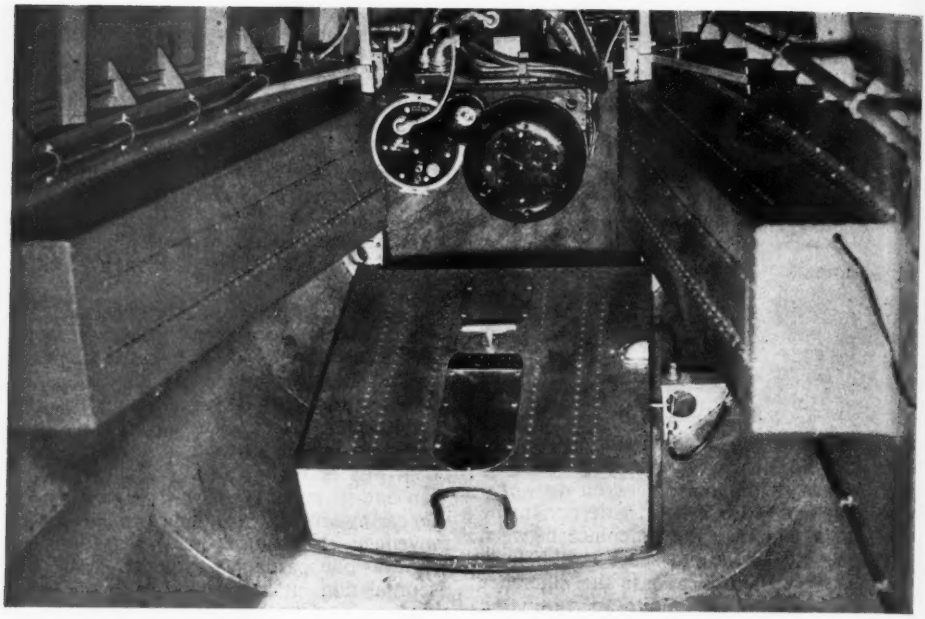


Fig. 7.

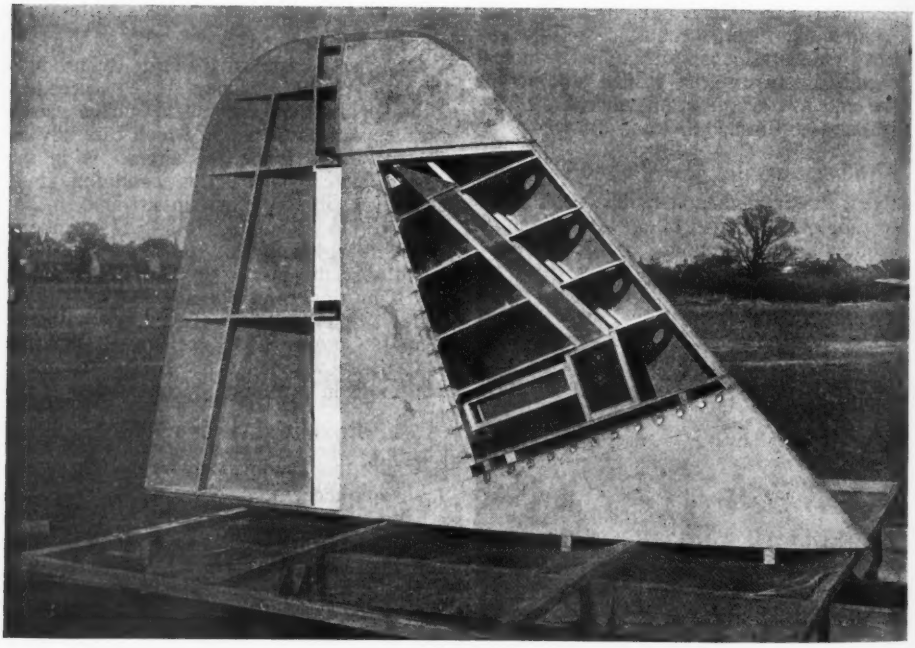


Fig. 8.

equipments, power supplies and automatic computers. In general it should be possible to place them outside pressure cabins, although some will be more reliable and lighter if placed inside.

Manipulated equipment includes dials on which data are set by hand, electronic controls of frequency, radar range scales, electronic markers on C.R.T. displays, and a host of on/off switches. It would be nice if these, and these alone, could be placed near crew members with remote control to their related equipment; but remote control brings its own difficulties and decreased reliability so that there is a tendency to place quite a lot of equipment with the control knobs and this makes a demand for space around crew members.

Instruments that have to be seen lend themselves more to remote control than do control knobs.

The multi-purpose instrument is possibly dangerous. Controls of similar appearance have led to accidents; they are even more likely if a single control has different functions.

Surely the present multiplicity of display instruments will one day tend to decrease; increased reliability and automaticity should slowly make this possible.

How much should an equipment be divided into separate units? This is a thorny question. There will nearly always be a division into four parts, namely:

(*a*) The detector, *e.g.* aerials and pitot pressure tubes.

(*b*) Manipulated and seen equipment.

(*c*) Other equipment.

(*d*) Power supplies.

Sometimes two of these groups can be combined in a single envelope. Coalescence increases reliability and decreases the number of cables, but makes less efficient use of the internal space of the aircraft.

6. THE CHOICE OF A NAVIGATIONAL SYSTEM

6.1. General

Some of the main military and civil requirements have already been mentioned. It is beyond the scope of this paper to discuss in detail the matching of these requirements from the almost bewildering choice of systems; comment will be confined to a few general points.

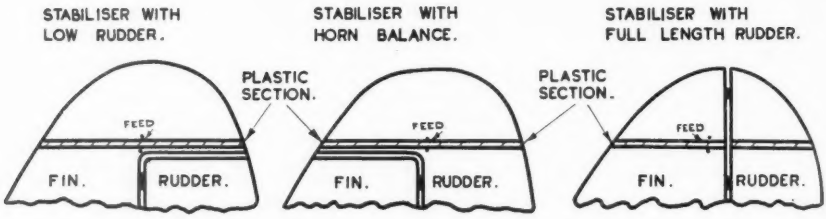
It is assumed that for flight planning and during flight, full use will be made of meteorological information, that a reliable communication radio service will be available, that for all except short-range operations with continuous fixing facilities D.R. will be used, supplemented by a fixing service. For the future it is assumed that anti-collision warning will be available and that ground surveillance will be used to cover over-land routes of high traffic density.

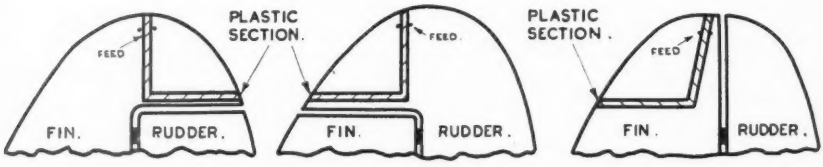
The main choice then, concerns the fixing services to be used. In the civil field urgent attention is being given to the relatively short-range service to be integrated into a traffic control pattern.

An elaborate and detailed scheme drawn up by Special Committee 31 of the Radio Technical Commission for Aeronautics has been accepted for the U.S.A. This will be based on the use of V.H.F. communications, V.H.F. omni-ranges and distance-measuring equipment with computors to enable pilots to fly in a prescribed lane, supplemented by ground surveillance enabling traffic to be controlled in blocks. Over a continent controlled by one authority and where traffic is heavy this scheme would appear to be necessary and ultimately sufficient, although its implementation will involve tremendous cost and will take at least 15 years to complete. Meanwhile, accuracy limitations of current equipment demand wide spacing of traffic lanes, and computors are unsatisfactory in cases where the track must be changed in flight.

For Europe the more flexible Gee service is relied upon, but for this integration with traffic control is not so readily achieved.

It is not easy to rationalise the long-range service with these short-range aids. Astro will remain as a useful standby with the introduction of the periscopic sextant and with increase in operating heights. Where a D.F. loop is carried, Consol would appear to be a natural choice involving no additional equipment in the aircraft. Loran has its champions, especially if combined equipment to use Gee is made available, the advantages being reliability and the unambiguous nature of the signal. It must be remembered, however, that widely spaced stations are required; this becomes impossible if, for example, Gee is required at an island site or along a coastal strip.





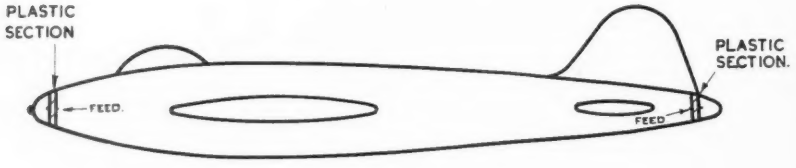


Fig. 9.
Possible practical illustrations of near-end feeding of aircraft.

6.2. Special roles

Survey flying calls for special navigational techniques. For small-scale coverage of large remote areas, such as that undertaken by the Colonial Survey, great use has been made of G-H beacons, in spite of the difficulties of siting and servicing. For large-scale survey of small areas the availability and accuracy of Decca at low heights has much to recommend it in areas where the service is available or could economically be provided.

The recent operations of helicopters for the carriage of mail is another instance where Decca appears to be very well suited.

Flight refuelling affords a further interesting example of a special requirement. The basic need here is for a good homing indication. Rebecca-Eureka is satisfactory provided that visibility is about half a mile or more. For use under worse conditions, something in the nature of a rapid scan microwave search radar and a responder beacon in the tanker might be a feasible combination. Since the tanker will normally be not too far from a ground station there should be no difficulty about the long-range navigation of the aircraft to be refuelled.

6.3. The future

How will navigational techniques contribute to the utilisation of aircraft in the future? A spectacular demonstration of the application of well-known principles was given on 21st September 1947 when the U.S.A.A.F. All-weather Flying Centre's C.54 flew from Newfoundland and landed at an airfield in Oxfordshire without intervention of any kind by its crew. As equipment becomes more reliable, certain duties of crew members will be eliminated one by one. We have the automatic pilot, to be followed by the automatic navigator and engineer; but a field for human judgment and decision remains.

For passenger travel a crew will be essential for an indefinite period, but it is possible to foresee the automatic delivery of mail and freight using take-off and landing conditions outside those which could be tolerated by human beings, so easing the serious problem of airfield space, and utilisation of existing airfields. The military counterpart would be the expendable pilotless bomber and would present a much more difficult problem; the very reverse of co-operation could be expected at the receiving end.

And so one returns to earlier thoughts of this paper, of the degree to which civil and military requirements differ. With ground assistance there is no fundamental problem; the civil problem is more one of organisation. However, for satisfactory traffic control it may be necessary to improve communications and display equipment and to reduce the errors of the fixing and computing systems. Quite different is the case when active opposition must be encountered; here, navigational effectiveness, taking into consideration other aspects of the operational role—reconnaissance, interception or bombing—must take precedence over simplicity or cheapness.

7. ACKNOWLEDGMENT

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DISCUSSION

E. T. Jones (Ministry of Supply, *Fellow*): The Navigators' Union in the last war fought a hard fight, as they all knew, for a good view downwards and the astro-dome was provided so that the sextant could be used to get as accurate a fix as possible. The war which they waged and won had now been lost in the peace. They would not now have the astro-dome, neither would they have a view downwards in the modern aircraft, but according to Dr. Adams and Dr. Uttley the periscopic sextant would not need an astro-dome. In the paper it was stated that at high altitudes there might be horizontal changes of wind speed of 100 knots in a distance of 100 miles and there might also be a change of wind speed of 80 knots through a height range of 12,000 ft. At the heights at which the modern aircraft would fly the need for getting accurate fixes was going to be more important as well as more difficult, especially since the aircraft speed would be high and the navigator would have much less time in fixing his position.

Dr. Uttley proposed to solve the problem by his "box of tricks," but if that equipment did not work all the time, and every time, they would still have to provide the navigator with adequate means of getting fixes visually or by solar means. Was the periscopic sextant adequate and suitable for that purpose?

The lecturers had rather skilfully avoided saying what equipment they thought was right as the airborne part of equipment as a whole. What, in their opinion, was the minimum airborne equipment of a non-radio type which would be necessary for a 2,000 mile flight at night in bad visibility?

Squadron Leader Bower (Air Ministry): He thanked the authors for an adequate and long-needed definition of dead reckoning, in terms of the open loop control system.

It should be emphasised that the quantities to be controlled depended on a factor, wind velocity, which was continually changing, sometimes in an abrupt and unpredictable manner, and that where control was required to a high degree of accuracy the time lag of the control loop became important. In such cases, and the blind approach phase was an example, the fixing process had to be continuous and it might also be necessary to introduce a rate term, as in the zero reader.

When arrival at a destination at a particular time and to a high order of accuracy was required, wind velocity became very important. The problem could be construed as one of maintaining a constant ground speed and the continuous fixing process was capable of producing the required error signals. What it could not do was to anticipate a future change of wind velocity. Consequently in the later stages of the flight the aircraft might be incapable of the adjustment in air speed necessary to maintain the time schedule, *i.e.* it was not sufficiently flexible, although it could have done so had the adverse wind condition been known in advance. That problem was probably confined to the military field, but it indicated that the interests of the aircraft designer and the meteorological forecaster might be inter-related.

By exercising the faculty of judgment the navigator could compensate to some extent for the deficiencies of the navigation aid, and it was right that that should be exploited to the fullest extent. As an example, a series of low accuracy fixes in rapid succession could be averaged by a simple graphical process so as to give an accurate indication of the aircraft motion, saving, perhaps, a much more complex mechanical operation.

There were other cases where the very nature of the fixing aid prevented continuous or even rapid position fixing and where the accuracy of those fixes was also low, *e.g.* long range D.F. and manual astro. There the theory of probability could be applied to advantage. Knowing the magnitude of the errors likely to be obtained in the various navigation quantities on a given percentage of occasions, it was possible to construct or deduce a most probable position so that although the exact position of the aircraft might not be known at any subsequent time it was always possible to assess the chances of being outside a particular area around the calculated position. That technique was used successfully on long ocean crossings. It demanded a detailed knowledge of the behaviour in accuracy of the navigation aid used.

There was another aspect to the same problem; for planning purposes as accurate a picture as possible was needed of the overall navigation capabilities of a particular projected combination of equipments, and he thought there was a need for a common agreed method of expressing the accuracy of navigation aids. Much had been done voluntarily in that direction, but there was still room for improvement.

The problem of the presentation and compilation of navigation information had to be considered most carefully in relation to the net gain, and it was there that he quarrelled with the authors' contention that in the military field navigation effectiveness had necessarily to take precedence over simplicity or cheapness. Economy of effort was an accepted principle of war, and in these days that effort had to include not only the fighting elements, but also the whole chain of producing and servicing agencies. He agreed that instrumentation beyond the presentation of plain position information was probably unwarranted, except in those cases where it required to follow a prescribed path—in time as well as position—to a high order of accuracy, but even there, as the authors pointed out, accuracy was accompanied by considerations of complexity, weight and reliability, which were governed almost entirely by the availability of suitable components. Reliability was just as important as accuracy and, he thought, there was a danger that in order to achieve an apparently attractive increase in overall navigation accuracy, either reliability would suffer, or alternatively, the Industry would be asked for an increase in effort which was out of all proportion to the fruits of that small increase in navigational effectiveness.

The authors had indicated the difficulties which lay ahead in reconciling the demands for increased speeds with the growing space requirements of navigation equipment. A related problem for the aircraft designer was the "customer who changed his mind." It had been a feature of the late war that the number and shape of the excrescences which had to be attached to the airframe waxed and waned with changes in tactics, theatres of operations and enemy reactions, and it was extremely important that this should continue to be possible. Dr. Uttley had shown that the tendency was for navigation devices, and aerials in particular, to become integral parts of the aircraft structure, from which it would appear that retrospective changes would become increasingly difficult. If this were so then there was a distinct danger that the aeroplane would tend to lose one of its most important military characteristics, that of operational flexibility. Did the authors consider this danger was real?

Group Captain E. Fennessy (Decca Navigator): The authors had presented a complete outline of all the systems, but had skirted the conflict which those who were associated with the details of navigational aid knew existed behind the scenes.

There were many devices, all of which claimed to be the best means of navigating an aircraft. Some were long range, some medium and some combined several claims, but it was known that no system at present came within reasonable measure of meeting ideal requirements. Nevertheless a great deal of energy was being dissipated and he thought the result would be that the aircraft as a means of flight would outstrip the means by which it could be got safely from point to point. That was a fundamental factor in the future of air navigation. It was no good having Comets or Brabazons which, as flying machines were ideal or near ideal, unless they were a safe, reliable, and economic means of transporting passengers. Aircraft would outstrip radio aids because the aircraft designer, although he might think he was being interfered with by everyone, had a large measure of control over his own instrument. He might battle with ministries, but nature was his real opponent.

The radio engineer had two distinct problems; he had to overcome the natural obstacles and limitations set by nature and, at the same time, to design a system which had to find its way through the maze of international conferences, which surrounded and—in the opinion of some—impeded the establishment of any system of radio aid to air navigation. He ran the gauntlet not only of technical differences but of national and international politics. No matter how adequate his system might be technically, he might still be faced with insurmountable obstacles. As a result the radio designer was likely to lag behind the aircraft designer.

That was the problem and it must be solved, otherwise they would have aircraft which were operationally unusable. There was no simple solution. Obviously there had to be international agreement but every effort

should be made to find ways to simplify and speed-up the task of developing and establishing necessary radio aid services. The radio designer would welcome a better definition of what was required; it must be far clearer, and more definitely expressed than at present, so he would know what the problem was which he had to solve. He might think he could define those requirements himself or discover them by discussions with navigators but this was not so and there was much confusion in setting out the requirements of navigational aid and by that he meant, in its broadest sense, the means by which the aircraft was guided from take-off to touch-down. That could only be done at a high level. It was the sort of work which the Ministry of Supply should be doing and it must be done by someone who could look at the problem very broadly.

Furthermore, there was a need for machinery by which systems which had been designed could be tested against operational requirements on a fair basis of comparison. It was no use everyone saying "I have the best system" unless someone was assessing the systems and using a fair standard of comparison—a sort of yard-stick. Without some method of judging and assessing systems a great deal of money was being wasted in the battle for navigational aids. It was a battle which affected the safety of those who flew today and certainly the safety of those who would fly in the future; the whole economics of air transport would be affected unless the radio engineer could keep pace with the aircraft designer. The radio engineer's problem must be adequately defined and the results of his design decided on a fair basis of comparison with the minimum of interference from elements not directly concerned with the safe and economic operation of civil aircraft.

S. Scott Hall (D.G.T.D.(A.) Ministry of Supply, *Fellow*): The Ministry of Supply had endeavoured in the past three or four years to play some part in the difficult matter of the co-ordination of the aircraft—the vehicle—and the equipment which was so essential for its operation. One of the great difficulties was that it was practically impossible for the aircraft designer, particularly in the present phase of aerodynamics, to say just what an extra half-inch in diameter of his fuselage was going to mean in terms of speed at the Mach numbers which they had reached. He would fight for that half inch because he suspected the effects might be much worse than anyone was prepared to tell him.

He thought the fears expressed that the aircraft designer was outstripping the navigational designer were unfounded. The aircraft designer realised only too well the limitations of his vehicle at the present time because of the high fuel consumption of the gas turbine and the absolute necessity of the aircraft being able to find its way in its scheduled time to its destination.

He thought that it must often appear to an aircraft designer responsible for the co-ordination of the aircraft as a whole, that it always seemed to be the system which was just around the corner which was the answer to the navigator's prayer and which meant a complete rearrangement of the installation. He wondered if those people who constantly asked for some new system realised what it meant in terms of wasted effort in the Drawing Office. He wished the authors had said a little more about the rationalisation of civil navigational systems and could have told them what progress had been achieved by international agreement on what systems should be adopted.

He felt strongly that captains of aircraft and navigators should be given equipment in the aircraft with which they could determine their own position, particularly in relation to other aircraft and obstructions. They should not have to rely on information transmitted from the ground. All civil aircraft should at least carry some equipment to tell them when they were in danger of collision. An analysis of the accidents which had occurred during the past eighteen months would show that a large number had been due to collision.

Dr. Uttley had referred to the crew disappearing one by one; he for one would give up travel by civil aircraft if that were the case! Dr. Uttley had also suggested, in the analogy of the earthworm, that the need to have brains and sensory organs at the front end had resulted in moving all the equipment to the front of the aeroplane. There was such a thing as the centre of gravity and one of the troubles was that it was always getting too far back for stability. That was one reason why all the weight went to the front!

W. A. W. Fox (T.A/D.Inst.R.D., Ministry of Supply): He thought that conflicts in aircraft design arose because they had not considered the equipment in the aircraft as a whole. The airframe was only the skeleton

and the engine the sinews of the aircraft; they could regard all the equipment as a single entity—as a brain, fed by radar and optical data as an ocular sense, and by 'communications' as the ears. With such a breadth of information to draw on they should consider the control system as a whole, rather than as a series of equipments.

The difficulty of unmanned aircraft seemed to him to be the existence of so many different equipments, none of which fully met requirements. No system which drew on only a few sources of supply for navigation data would be adequate at the present time.

Perhaps if they looked at individual applications the picture varied. There was short-range civil navigation particularly, with its close ground control in the form of traffic-control and lane flying, in which, he thought, they were at least dependent on the human element, but there they were biased. as had been pointed out, by the fact that both personal and legal factors would demand the presence of a captain of aircraft with some kind of monitoring function. In long-range civil applications, so far as he could see, the navigator would still retain his place, first because long-range aids required a skill and discrimination in reading which was not immediately applicable to the types of control envisaged by Dr. Uttley, and secondly because the weather was becoming more, rather than less, important. As had been pointed out, the ratio of wind vector to air speed vector was about 30 per cent., whereas in the future it would go up to 40 per cent. at a time when the high fuel consumption of jet aircraft made endurance much more critical. Thus in the long-range application the role of the navigator would be rather more arduous than it had been.

In the military field there seemed to be two trends, in the first type towards the complete elimination of the crew and in the other towards a greater reliance on their discrimination and brain power. The first type had to depend on a perfect navigational aid and the emphasis, for economic reasons, was on simplicity of design. The disadvantage of this type was the vulnerability of such craft to counter-measures.

Therefore the second form of military craft would remain in existence because, for immunity from counter-measures, they had to use the human power of discrimination and a wide variety of navigational aids.

From the point of view of the practical navigator, the interesting point was likely to be what exactly would be his activity in the future. In the realm of pure Dead Reckoning he thought they could take the burden from him with instrument systems, but they had yet to discover the best way in which he could use his discriminatory power. That was to say, to take his mental work even beyond the pure assessment of probable errors into, perhaps, diagnosis of the working of the individual equipment. Such a change in his activities would require a lot of thought on the presentation of the equipment beyond what had already been given to it. Even so, he imagined that the navigator would still have to cope with a complete breakdown of his instrumental services and fall back from time to time on the old-fashioned methods of "pencil and paper," and it was an interesting question how far such methods would be retained (if only to keep him in practice) in an age of instrumentation.

H. C. Pritchard (Royal Aircraft Establisnment, *Fellow*): He was surprised that they had not yet heard much from the aircraft constructor. Both the user and the constructor were necessary to contribute to the compromise which had to be made in almost all airborne equipment. One technical field, briefly mentioned by the authors, which could give assistance to both the user and to the aircraft designer, was in the provision of small electrical and mechanical components. There, he thought they had lagged behind other countries, and the lack of what, in fact, were the "nuts and bolts" of the modern equipment designer must in the long run have a bad effect on the equipment produced.

One point which followed from the paper was that navigation systems for high subsonic speed aircraft need not differ radically from those available for existing aircraft. It was interesting to speculate, however, whether the supersonic aircraft could give a fresh approach to the navigation problem, in that reduced times of flight would follow, since the distances between terminals, and the size of the earth, were perhaps the only fixed things. Methods which made use of that feature might become practical and systems dependent more on direct measurement of the ground velocity might play their part. He thought such measurement would also be needed for the problem of guiding and

landing high speed aircraft, since accuracy in time of arrival would be assisted by continuous and accurate knowledge of the ground velocity.

Sir Robert Watson-Watt (President of the Institute of Navigation, *Fellow*): The chairman had asked him to review the discussion. He thought the paper contained a valuable series of warning sentences about the difficulties of satisfying even the most modest demands of the long-range aircraft operator —military or civil.

They might well have invited the President of the Royal Meteorological Society to sit at the President's left hand, because it would appear that if, in fact, the aircraft were temporarily outrunning the aided navigator, both of them were rapidly outrunning the meteorological knowledge on which the final decisions as to aircraft utility, aircraft design and the choice of the navigational aids had to be based.

Was he right in taking from the meeting a sense that a further large extension of their meteorological investigating systems was of the essence of any solution of the long-range navigational problem?

The recent brusque intrusion of the "jet stream" into their previous happy assumption that the stratosphere was a comparatively peaceful place was only one outstanding example of their continuing ignorance of the detailed meteorology of the regions in which they chose to fly.

The discussion revealed the dual difficulty of stating exactly the kind of help that was most needed and of knowing exactly what each type of equipment could dependably do in practice. He hoped that in their reply the authors would sort out the heads of this wide-ranging discussion into a few groups, for example, (*a*) the discussion of instrument aids to navigation as a means of effectually extending the range of the observers' senses; (*b*) the means of reducing the demands made on the purely mechanical side of the human brain in arriving at what ought to be a unique solution from a comparatively small number of numerical data; and (*c*) the examination of what the remaining man or men in the machine were being freed to do.

Navigational-aid men were attempting to reduce the burden and "distraction value" of navigational duties by providing appliances, more flexible and more subtle than those formerly built into the machine to reduce the effort, time and strain of making observations and to reduce the tax on the man's attention that was imposed by paper arithmetic. But from that point on it seemed to him the discussion had been in danger of losing itself.

There had been a diversity of views on the way in which the man in the aircraft might use the mind thus relieved. He even suspected a certain element of mysticism as, in the allegation that human judgment was best in the extraction of the most probable value from a set of not wholly accurate observations. He rather suspected that this belonged to the same ways of thought which, in the long past days of classical direction finding, so often resulted in the captain of the craft deciding that none of the D/F observations could possibly be right because they disagreed with his D/R. He did not think they could accept that kind of mysticism as valid but he hoped they would not, on the other hand, cast the captain of the aircraft for the role of machine-minder. He hoped he would not, for example, have the duty of making sure that all the valves in the radio were working at the right point on their characteristics. But what *was* he going to do? Was he to knit until the gadget broke down—as it would? And then what?

He thought the satisfactory analysis which Dr. Uttley gave the system might well be applied to the people in the system, perhaps in a new paper on "The Mind in the Machine," and might be applied to discussing, in a highly philosophic and non-prejudiced spirit, what in fact man was for in air navigation.

Group Captain Fennessy had referred to designers having to fight their way through the serried ranks of committees. There was an element of truth in it. Committees were tiresome things, but they were also beneficial, because after they had stripped away the inessentials, the Ministries honestly tried to achieve the essential things. The committees were in large measure there for the purpose of bringing forward objections, the very awkward and jagged bits of nature which stood in the way of any one of the proposed solutions being anything like an ideal solution. It was true they had not a system anywhere near being perfect, but he had found no way of getting a balanced picture of the awkward interventions of nature except by getting a considerable number of people together, each with a particular bee in his bonnet as to which bit of nature was the most

serious in its opposition to the success of any solution under discussion. He had regarded the "psychological" side of the discussion as being much more important than the "physical science" part of it.

He hoped the authors would deal specially with the important point raised by Squadron Leader Bower—the need for the preservation of freedom to change their mind, particularly in warfare. The need for flexibility, even at the price of considerable inconvenience to the aircraft manufacturer, was indisputable.

He regretted that Sir Frederick Handley Page was not present. He remembered the distress which "H.P." expressed, on the last occasion on which they had been together on that platform, about what the providers of aids to useful and purposive flight did to the beautiful aircraft which the constructors provided for fast flight.

THE LECTURERS' REPLY

DR. ADAMS: Sir Robert Watson-Watt had asked if he had interpreted the paper correctly in assuming that the solution of the long-range navigation problem lay largely in an extension of the meteorological investigating systems. The efficient utilisation of aircraft demanded all that could be given by the meteorologist for *planning*, both civil and military. But, because of inevitable uncertainties in forecasting, a clear appreciation of meteorological systems must also be possessed by the captain of aircraft.

The role of the captain in an aircraft fitted with sophisticated automatic aids had also been discussed. Human judgment was required in assessing changing circumstances, including weather, enemy interference, or emergency conditions of any kind. There was no suggestion in the paper that the whole crew could be eliminated from passenger-carrying aircraft—a fear expressed by Mr. Scott-Hall. The same consideration might apply in the military field in circumstances where the success of one particular mission was vital.

Another broad topic, which had been stressed particularly by Group Captain Fennessey and on which Sir Robert had commented, concerned the choice of system and the determination of the most generally desirable combination of features. Within the limits allowed, they could not venture to enlarge on such debatable factors as the lines along which international agreement was proceeding. Their avoidance was quite deliberate. For the same reason he thought it unwise to pursue certain questions of application which had arisen in the discussion but he heartily endorsed the demand for a sound appraisement of navigational systems. A clear guide to the equipment designer would result in conservation of technical effort and in an improved rate of progress towards the stated ideal.

DR. UTTLEY: He agreed very much with Dr. Adams, that the need for better meteorological information would steadily increase, both because of increasing speeds, and the demands for more accurate navigation. He also agreed with Squadron Leader Bower that, having progressed to suppressed aerials, the next step for military aircraft would be to consider how they might be made more flexible of installation.

The rate at which automaticity would grow in aircraft navigation would depend primarily on progress in reliability.

The tasks which did not require judgment or decision would eventually all be carried out by mechanism. The man then left might be called a captain; he would make the decisions now undertaken by both pilot and navigator. In civil aircraft carrying a large number of passengers the technical crew might be reduced to one such man and a deputy.

With a really complete meteorological service the *en-route* navigation of private aircraft could be made automatic; ultimately, with improved instrumentation, the human skill required in private flying should be of no higher order than was now required for driving a car.

THE PRODUCING OF A PROTOTYPE AIRCRAFT

by

C. T. WILKINS, A.F.R.Ae.S.

The 790th Lecture to be read before the Society was given on 9th February 1950 at the Institution of Civil Engineers, Great George Street, London, S.W.1. Sir John Buchanan, C.B.E., F.R.Ae.S., President of the Society, introduced the Lecturer, C. T. Wilkins, A.F.R.Ae.S., Assistant Chief Designer, The de Havilland Aircraft Co. Ltd.

1. INTRODUCTION

In presenting this paper on the producing of a prototype aircraft it is not the author's intention to deal with the overall conception of the type or such matters as operational requirements, performance, type of construction and so on, but rather to start from the point where the general arrangement of the aircraft has been drawn and to try to describe what, in his opinion, should be the best way to produce the aircraft in the shortest possible time and at the least possible cost.

This subject has been dealt with before, particularly in the second part of the excellent paper by G. R. Edwards*, and others, but whereas they have approached the problem from the point of view of the chief designer, the intention here is to do so from that of the assistant chief designer. There is always more than one way of doing a job, particularly one of this nature, and another opinion by a member of a different firm may be of interest. The subject, therefore, has been gone into in somewhat more detail.

The views expressed are the author's, and are not necessarily shared by the de Havilland Aircraft Company, although many of them have naturally been formed as a result of his experience with that Company.

*Problems in the Development of a New Aeroplane. G. R. Edwards, M.B.E., B.Sc., F.R.Ae.S. JOURNAL R.Ae.S., March 1949.

2. CONCEPTION OF PROTOTYPE

Broadly speaking there are two kinds of prototypes: the research aircraft from which to obtain specific data for a future production aircraft, and the first of a production order.

If the project is in the first category, then it is right to build one or two aircraft only, but if it is in the second category production aircraft should be built concurrently with the prototype starting as soon as possible.

An aircraft for production should represent a large enough advance in design to reach a potential market and by development of the type to hold this market for many years; yet it should not be so radical in conception as to make it unwise to proceed with quantity production without first test-flying a prototype. The skill of a company can be measured by its success in judging the size of the step in design which should be taken to meet this requirement.

Too many aircraft are built first as one or two prototypes, taking possibly two years or more to build, followed by perhaps one year of test flying and modification to get it right before production really gets going. A further period of two years may elapse before the first production aircraft is delivered to the operator, who may spend a further year in proving flights before the aircraft reaches operational service, making, say, six years from the time when the prototype was started to the time it goes into operational use, and this may well be considerably longer for large aircraft.

This is far too long, as during this period new developments in operational requirements, power plants and so on may take place which, if incorporated in the design, will cause still further delays, but if not incorporated will render the aircraft obsolescent before it reaches operational service. It is far better to face modification on the

production line than to wait for prototype development, so that a batch of operational aircraft can be delivered to the operator at the earliest possible moment and experience in actual operation be obtained. In the meantime, the type can be developed incorporating any developments and also, any points which may arise from the operation of the aircraft.

The foregoing remarks are obviously more applicable to large or complicated aircraft than to the small or simple aircraft, as the time factor is greater in the former case. For example, it would obviously pay to get the prototype of, say, a Moth right before starting production.

3. FACTORS GOVERNING THE TIME TO PRODUCE A PROTOTYPE

Time is the all-important factor in the producing of a prototype. There is nothing worse than a project which drifts on and on, repeatedly being altered until everyone is heartily sick of the whole thing, enthusiasm flags, the costs rise and the whole project suffers.

The detailed scheming and design should not be started until the general conception of the aircraft has been settled and a rough idea of the way of doing the job is known, after which major decisions should be given without delay. A great deal of exploratory work will have been done before this stage is reached, but that is outside the scope of this paper. Once this stage is reached, the job should be pushed forward with the utmost viguor, and everything should be done to keep up the enthusiasm until and beyond the first flight.

3.1. Size of team

The team should be kept as small as possible, consistent with the amount of work released. There should be a nucleus of senior designers and their assistants, allocated to the job who will remain on the project from start to finish.

In addition to this nucleus, there should be a pool of junior designers and draughtsmen which can be drawn on as the work becomes available and returned to the pool as the work falls off. Time is not, as a rule, saved by piling more and more juniors on to the job, as this results, as often as not, in the far more valuable seniors spending all their time supervising and instructing the juniors, instead of getting down to the job themselves.

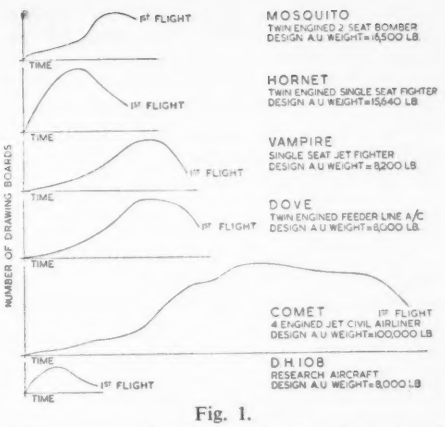

Fig. 1.
D.H. prototype aircraft—drawing boards employed.

Figure 1 shows the number of drawing boards employed, plotted against the time taken from the start of the design to the first flight, for six prototypes. The chart is self-explanatory, but it might be of interest to point out that the first three aircraft were built during the 1939-45 War and the rest after the war.

It will also be noticed that on the two development types, namely, the Hornet and the D.H.108, it was possible to supply the maximum effort at an early stage, whereas on the new types a long period of investigation was necessary. It also shows that large aircraft require a far greater effort, but this extra effort is required mostly on the parts of the aircraft other than the main structure.

3.2. Target dates and programme

Soon after the start of the design a target date should be set for the first flight. This date should be on the optimistic side, but at the same time should be as realistic as possible. Nobody will take any notice of an absurdly optimistic date.

Based on the target date for the first flight, a detailed programme should be prepared in conjunction with the experimental shop, showing at what times the various units should be ready for assembly to the aircraft. By working backwards it should be possible to fix dates for all the various stages of the job, such as tooling,

jigging, provision of materials, special equipment and so on. The times for the issue of drawings to the shops can also be fixed and any falling behind of these can be brought up at the weekly progress meeting.

The programme should be kept flexible and it will be found that as time goes on a periodic revision will be necessary.

3.3. Progress meeting

A progress meeting should be held periodically with the chief designer, stress office, aerodynamics department, senior designers, technical buying, experimental and production shop represented. The main object of this meeting is to keep a check on the progress of the job, to let people know what is going on in a general way and to let them bring up any points, such as information required from the aerodynamics department or stress office. This meeting also serves to keep the specialist, such as electrical and hydraulics, and the technical buying department in the picture, so that early enquiries can go out for proprietary equipment. This meeting should in no way be a design conference and it is not here that any design decisions should be taken.

The meeting should be of short duration and should in no way replace the very close personal co-operation between departments and individuals, so necessary to ensure that the whole organisation works as a closely knit team.

Meetings and conferences generally, whether internal or external, should be as infrequent, short and as small as possible, as they can be shocking time wasters and people are apt to think that all problems can be solved at a meeting and will tend, therefore, to wait for the meeting before getting on with the job.

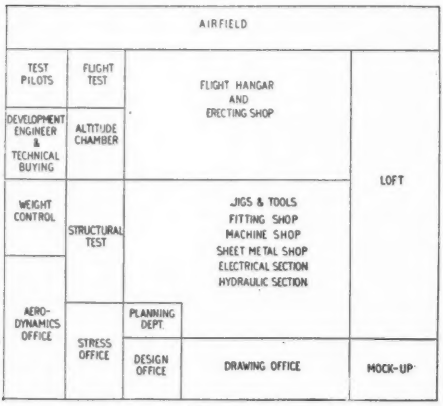

Fig. 2.
Ideal layout for experimental department.

3.4. Layout of experimental department

Figure 2 shows diagrammatically an ideal layout for the experimental department.

It is most important that all departments be grouped closely together. It is a matter of choice, but the author's preference is that each department should have its own office, thereby giving each member of that department a feeling of being part of a small team, thus retaining their own individuality, rather than having the feeling of being just a cog in a large machine. By this it is not meant to imply that these departments should be water-tight compartments; on the contrary there must be the closest personal contact between the members of the various departments.

It is also important that the experimental shop, mock-up and loft should be readily accessible to every member of the design team, in order that they should feel that they are literally on top of the job all the time. All members of the design team, including the juniors, should at all times be encouraged to go into the shop and see the results of their work in the flesh, and thereby gain experience to do better the next time.

It will be noticed in Fig. 2 that the whole of the department is adjacent to the airfield, with the flight hangar, flight test and test pilot's offices overlooking it. The experimental shop is centrally disposed, being accessible to as many departments as possible. The whole of the design department is grouped for close co-operation with the weight control adjacent to the aerodynamics department, the structural test adjacent to the stress office and the loft and mock-up adjacent to the drawing office. The loft is also accessible to the experimental shop.

3.5. Overtime

The maximum possible amount of overtime should be worked, bearing in mind the following points: Overtime is costly in salaries, but money is always saved by getting a job out quickly, due to the reduced time for which overheads are being paid and other

factors. Too long hours should not be worked and regular breaks in overtime should be provided; otherwise, people will get stale and no benefit from overtime will result. Ideally, overtime should be worked on only those jobs that have been settled in principle. There is nothing worse for a man's morale than to work long periods of overtime on a job that he is unable to get on with because someone has not made up his mind as to what he wants.

On a large aircraft a long and sustained effort is necessary if the project is not to drag on and overtime only on certain sections is not enough. Should any section be unable to get on with its job, members of that section should be transferred to other sections which can. In any case it is difficult to persuade some people to work overtime and not others and the only course left open seems to be for the whole department to do so.

3.6. Chasing

Ideally, forward planning should obviate the need for chasing, but as this can never be perfect a certain amount of chasing becomes necessary as the job proceeds. Apart from the organised chasing done at meetings, a great deal can be done by the designers themselves in direct contact with the shop. Only the urgent jobs should be chased because if this is overdone all jobs assume equal importance and the whole value of chasing is lost.

4. DESIGN DEPARTMENT ORGANISATION

An efficient design team capable of producing successful prototypes quickly is probably the most valuable single asset that any firm can possess, and although not the complete answer, the logical planning of a design organisation can be a great help in ensuring the smooth working of the design team. Everyone has his own ideas as to what such an organisation should be. Usually such organisations tend to happen rather than be planned, depending as often as not on the personalities of the people concerned, the layout of the factory and many other factors. The author can only express opinions based on many years of experience in an organisation which has been found to work reasonably well.

Figure 3 shows such an arrangement, but it shows only the broad outline and could be broken down into much greater detail. The whole of the design organisation, including the experimental shop and technical buying department, is responsible to the chief designer.

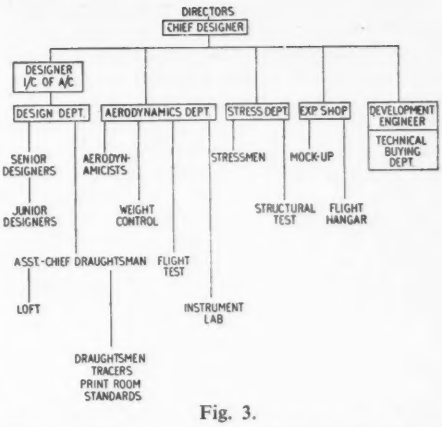

Fig. 3.
Chart showing composition of design department.

If more than one prototype, even of entirely different types, is being built concurrently, which with the rapid development of modern aircraft is so often necessary, they should all be designed and built within the same organisation. It is no use trying to set up a number of separate design organisations, as a successful design team is not made overnight but is the outcome of years of selection to build up an efficient team.

Obviously the drawing office must be split up into sections, but they must all share the same facilities, such as the stress office and structural test, aerodynamics, mock-up and experimental shop, and have available to them the wealth of collective experience and data which has been built up over many years.

4.1. Delegation of Responsibility

The days when one man could design in detail the whole aircraft are long since past and the chief designer must now delegate a great deal of this responsibility to others. At the same time he must know what is going on in some detail and must guide the whole project through its various stages. The fact that key personnel are unavoidably absent, due to illness, holidays and so on, should not affect the overall working of the team if responsibility has been properly delegated.

There is a great temptation to take a good senior designer off a project as soon as he has completed the main part of his unit and to leave a more junior member to carry on with the relatively unimportant details and any modifications that may become necessary. This is bad practice, since it is just as easy to throw weight away and to have trouble in service with the seemingly unimportant details as on the main structure. If it is at all possible the senior designer should see the job right through, at least until the aircraft has flown and preferably, until it is well into production.

4.2. Supply of new talent

One of the difficulties of the present time is the limited supply of good senior designers, capable of taking charge of a complete unit and running a section. Since this type of man is usually already employed and is unwilling to leave his present employment because of housing difficulties and other factors, the importance of a technical school run by the firm is at once apparent. Students entering the drawing office straight from the technical school can be trained from the start to work in such a way as to fall in with existing set-ups, thereby ensuring continued smooth running of the organisation. Some of the best men have been recruited in this way; they are not necessarily university graduates or men with other academic qualifications, but are sound practical engineers with a good basic training.

4.3. Drawing office systems

Systems generally should be as simple as possible, involving the absolute minimum amount of paper work. The part number system, by the arrangement and character of the numbers comprising it, should give an indication as to which aircraft, and to which unit of that aircraft, the part belongs.

Even though the aircraft is in production concurrently with the prototype a full modification system should not be introduced until the last possible moment, preferably not before the aircraft is in operational use and certainly not before the prototype has flown. A simplified modification system, however, must be employed to record changes introduced during the development of the prototype, for interchangeability and spares supplies.

4.4. Standard of drawings

In order to keep down the number of men on the job the drawings should be of the minimum standard required to build the prototype. To save time, as much information as possible should be put on one drawing.

If the experimental department can build the aircraft from these drawings, so can the production department, provided that every item is dimensioned correctly and has a part number. When production really gets going these drawings will need to be broken down and made into proper production drawings in collaboration with the production department. This will be the job of the production drawing office.

During the building of the prototype verbal instructions may be given to the shops, by responsible designers, but they must see that the information given is incorporated on the drawings immediately.

4.5. Checking and issue of drawings

It is not possible to check every dimension on every drawing as this would mean that the checker would have to lay out the job himself, or check the designer's layouts. This is not practicable, but endless re-issues of drawings, involving sometimes as many as 15 or more prints, can be avoided if the drawings are checked for obvious mistakes; the author knows of a case where an undercarriage was laid out, issued and parts of it made half-scale.

In order to get the job going as quickly as possible in the shops, the drawings should be issued to the stress office for check stressing at the same time as to the shops and not held up in the stress office before issue. In general, it is better to start the job quickly with the risk of possible scrap, rather than to delay starting it. Drawings should also be issued as they are made and not held up until all the details and the G.A. are complete and then issued. This overloads the methods engineers and causes delay in starting the job.

The production department, including methods and planning engineers, should also see all prototype drawings as they are issued, so that the aircraft can be planned for production at an early stage, and one or two members of this department should be stationed in the drawing office, where they are available for consultation on all points of manufacture.

4.6. Simplicity

The modern aeroplane has become so complicated that if the present trend persists much longer it will no longer be a practical flying machine, but a box of tricks which spends most of its life on the ground being made serviceable.

Simplicity is the keynote to reliability, ease of maintenance, lightness and cheapness. This fact cannot be too strongly instilled into every member of the design team from the students upwards. It is the easiest thing in the world to allow a design to become complicated and full of gadgets, one thing being added to another to make the thing work at all. There is nothing clever in this.

Periodically the designer should stand back and ask himself: "Is everything incorporated in this design absolutely necessary? Are there any relics from a scheme which has since been altered? Is something still being done in a certain way because it suited a previous scheme?" Some schemes get so complicated that one has to say "If the particular feature under consideration means all this, we had better abandon it and do something else."

4.7. Equipment

Equipment is a most fruitful field for weight saving and the elimination of complication. The equipment designer is obviously a specialist in his own line and will tend to subordinate all else to the perfection of his own product, and it is up to the designer to strike the right compromise between what suits the equipment and what suits the aircraft. With military aircraft, the designer cannot do much about that equipment which is specified in the requirements, since this is standardised to a large extent for all types, but he still has control over non-military equipment such as hydraulic and electrical gear. On a new civil aircraft practically all the equipment, at the present time at any rate, will be new and it is up to the designer to keep a careful check on it.

When considering new equipment the designer should first satisfy himself that the particular piece of equipment is really necessary. Secondly, he should ask himself whether the job cannot be done in a more simple and reliable way. For example, a straightforward cable-operated throttle control is a far better proposition than some clever electrically or hydraulically operated remote control.

No new equipment should be accepted at its face value, but should be studied in detail and discussed with the manufacturers with a view to improving simplicity and lightness. The fact that the equipment has been used on some other type, although valuable in that experience has been gained with it, does not necessarily mean that it is suitable for the current type.

On all new equipment the aircraft designer should lay down his own series of proving tests, whether these are done by the aircraft manufacturer or by the equipment manufacturer, and no new equipment should go into the prototype until these tests have been completed satisfactorily. The manufacturer of new equipment is often tempted to use the prototype as a guinea-pig to prove his equipment. This cannot be tolerated as it inevitably leads to serious, or at least annoying, delays during the prototype flying.

It is a controversial point whether complete units, such as undercarriages and hydraulic systems, should be handed over to the specialist firm to be designed and manufactured, with the responsibility for such work resting with the specialist firm. It is the author's view that all the design work should be done by the parent firm and advice of a specialised nature sought from the specialist firm. In this way a much closer check can be kept on the job and the designer is not completely in the hands of the specialist on detail points, while at the same time he reaps the benefit of the specialist's knowledge of design and manufacturing technique.

4.8. Standardisation

Without in any way detracting from the excellence of the work done by the S.B.A.C. Standards Panel, the author believes that standard items should be confined to the smaller parts and no attempt should be made to standardise things like controls, seats and cockpit layout generally, as items of this kind are an integral part of the aircraft and should be designed as such.

On military aircraft the general disposition of instruments, controls, and the like, can be recommended, but the exact position and type of unit should be left to the aircraft designer. It is so difficult in the design of a successful modern aircraft to strike the exact balance of conflicting requirements that any built-in compromises, such as large

standard items, cannot be afforded if the best possible design is to result.

In many years' time, when designs have become far more stabilised than they are today, it may be possible to design a standard fighter cockpit as a unit complete with instruments, controls, seat, and so on, around which the rest of the aircraft is built. In the author's opinion this is doubtful.

5. DRAWING OFFICE

Before discussing the functions of the various departments shown in Fig. 3, a plea must be made that the word " draughtsmen " be used only in its proper place. So many people refer to anyone who works at a drawing board as a draughtsman, but anyone who has anything to do with design knows that the man who schemes say, a main wing joint or an undercarriage, is poles apart from the man who is capable only of making pictures to instruction; yet they are both referred to in the same terms. It is time that the man who does the basic design, even though he works at a drawing board, was given a title commensurate with his high degree of intelligence, experience, technical knowledge and sheer ability, and not classed in the same category as those who are capable only of drawing pictures.

Also, this whole occupation of aircraft design should be more on the basis of a profession, such as, say, that of an architect, rather than being considered as something between a trade and a profession. The work of an aircraft designer calls for far more original thought and practical experience than many of the older professions; people's lives are dependent upon his work and the information required to do his job, as a rule, cannot be obtained from a textbook, but must be acquired as the result of his own experience and intelligence.

5.1. Requirements for a good designer

In the author's opinion, a good designer must first of all have enthusiasm for his job, a good technical knowledge and an interest in aeroplanes generally, and if he is not a pilot he should have as much flying experience as possible and be willing and eager to fly in the prototype when occasion demands. He must be quick to appreciate the point when it is explained to him and quick to give effect to it. Mistakes he may make, but they should not be major ones and should not be repeated. Anyone who makes no mistakes certainly makes nothing else.

He must also have a co-operative personality, for however brilliant a man may be he will be completely useless if he is unwilling to co-operate with other people. He must be willing to put in long hours of overtime, even to spending whole week-ends on the job; above all, he must have creative ability and a flair for devising the best way of doing a job simply. This will not be found in any book. He must have a sound basic mathematical and mechanical training, followed by, or concurrently with, practical experience in the shops. There is no need for him to be an artist. The quality of drawing may be likened to handwriting and in fact serves the same purpose in conveying ideas on paper from one person to another, and as such is no more or no less important. Provided both are clear and legible they need be no more than that. Many youngsters are put into a drawing office because they can draw. These are usually the people who remain draughtsmen all their lives.

When the designer has acquired the above qualifications, it might be said that he has been provided with a set of tools for the job. He now has to show that he can use them.

5.2. Stressing by designers

During the early stages of the design, the senior designers will have to work very closely with the stress office to determine the size of main members, such as spars, skin thicknesses, stringer spacing, and so on. When these have been fixed and the stressing becomes more detailed, the designers should do their own stressing and not expect to get the size of every detail from the stress office.

When the scheme is completed, it can then be check-stressed and finally stressed when the drawings are issued.

5.3. Layouts and schemes

When the designer lays down a scheme in the early stages of the design, he should endeavour above all to give a clear overall picture of what is intended, so that not only he, but also his senior who has to approve the scheme, can see what is intended. The main loads applied to the structure should be clearly shown so that some idea of sizes can be conveyed. All relevant details, in outline, should be shown, as should

surrounding structure, to indicate clearances. There is nothing worse from the point of view of the senior who has to approve the job than to be presented with a mass of 6H pencil lines or some vague half-finished scheme, which may mean something to the man who put it down, but certainly does not to anyone else.

Accuracy is not important at this stage as final dimensions can be obtained from the finished scheme after it has been approved. For subsidiary jobs attached to the main existing structure, this structure should be laid down first and the scheming done on an overlay so that several ways of doing the job can be tried without endless layout work.

It is most important that all piping, wiring, control runs and so on be laid out carefully at an early stage of the design. In the past it was common practice to concentrate on the main structure, leaving piping and wiring to find their own home later. So complicated has this work now become that it has assumed the proportions of a major job and should be treated as such.

5.4. Specialities

A controversial point which always arises in the composition of a design team is whether to keep a man permanently on one type of job. This depends largely on the type of job in question. For example, it is not right to have specialists on structural work so that a man only designs, say, fuselages or tail units. The danger here is that he tends to become stale and puts the same ideas into a new design as he put into the previous one. It is better to move these men from unit to unit and so build up a team of versatile designers capable of taking on any unit on the aircraft.

Certain sections of the aircraft, however, do demand specialist's treatment. These may be listed as

1. Radio and electrical systems
2. Undercarriage and hydraulic systems
3. Engine installation and fuel systems
4. Pressure cabin systems
5. Armament.

The specialist, like any other member of the team, cannot be allowed too free a hand and must be prepared to fall in with the overall conception of the aircraft and to account for his decision to the chief designer in terms which the chief designer can understand; he must not try to make a mystery of his specialised subject.

The fact that a specialist firm has been called in does not in any way relieve the aircraft designer of the responsibility for the strength, weight or correct functioning of the equipment. As mentioned previously, this is his responsibility and this fact must be impressed upon the specialist firms.

5.5. Chief draughtsman

The chief draughtsman, who is responsible for the whole of the drawing office, will employ two assistant chief draughtsmen, one to deal with the production drawing office and the other with the experimental drawing office. It is the function of the latter that will be discussed here.

The assistant chief draughtsman should act mainly in an administrative capacity, and is not required to take any major design decisions. He should, however, keep an eye on design to suit production, the use of standard parts, material and protective treatments. He should also be responsible for the discipline of the office, time keeping and the allocation of personnel to the various units. In addition, he should issue and keep up to date the data sheets and standard parts book, besides being responsible for the correct functioning of the part number and modification systems. He should lay out the office into sections working on different units, so that close co-operation will exist within these sections. Records of man-hours worked on various jobs must be kept and estimates of the number of men required, and the design costs for future projects must also be made for the information of the chief designer.

The assistant chief draughtsman should be responsible for the planning of the whole job in programme form and should bring to the notice of all concerned any falling behind of the programme.

5.6. Loft

The assistant chief draughtsman should be responsible for the loft. This has become an essential department since the advent of metal construction and it is found to afford the only practical method of obtaining full-scale layouts for the manufacture of production and prototype tools. These full-scale layouts, in any case, have to be done at some stage and if not done in the loft would have

to be done later in the shops. They are also extremely useful in the drawing office at a later stage when, for example, installing equipment, because the full-scale layout being available from the loft, the designer is saved the necessity of laying out the job himself. Besides being more convenient it represents exactly the actual job. Furthermore, the dimensions on the drawings are automatically checked and, the loft being under the control of the drawing office, any error can be corrected before anything is made.

It was thought at one time that with the loft technique many dimensions could be omitted from the drawings. This is true of cowling lines, rib profiles, bulkheads and the like, but it is found that detail parts must still be fully dimensioned.

Many parts of a modern aircraft can be faired in with sufficient accuracy only by means of full-scale layout. This work is a charge on design, but the preparation of tool templates, and so forth, is charged to production.

6. STRESS OFFICE

In the early days of the simple biplane most of the stressing of an aircraft was of an elementary nature and in general could be done by the senior designers themselves as they went along, once they were given the main external loads which were applied to the structure. The main function of the stress department was then of a checking nature, also the subsequent preparation of the type record.

In these days, however, when a modern aircraft structure presents probably the most difficult and refined structural problem of any branch of engineering in the world, the importance of the stress department dealing with such a structure will be apparent. So complex indeed has the problem become that theory goes only a certain way to achieve the optimum structure and recourse must be had to full-scale testing. The value of this full-scale testing is not only to prove the strength and stiffness of the particular structure in hand, but also to build up a wealth of experience, with the result that subsequent structures can be designed far more closely to the required strength and stiffness than by theory alone. It is important that this testing be done on the spot, so that both designers and stressmen can watch the test in progress and reap the benefits of visual observation, instead of by reading a report.

Every component on a new design of aircraft should be tested, either to destruction or proof loaded. Great emphasis must be placed on repeated loading and fatigue tests. It has been found that by comprehensive testing in the detail stage, trouble-free tests of complete components are usual.

6.1. Prototype Stressing

The first consideration in design is stiffness, which in most modern high-speed aircraft governs the skin thicknesses. After the skin thickness and type of stringer have been decided, rib and frame spacing should be fixed and test panels put in hand to confirm stringer pitch and to determine the permissible stresses of the panel as a whole. At an early date balance-out calculations should be made in order to give preliminary loads to the drawing office, so that schemes can be started.

All loads are given to the drawing office on stress office data sheets and these loads should be less than the estimated values to allow for the fact that designers always work with a bit in hand. All sizes fixed by the stress office should be the absolute minimum, as all structures are finally tested. In doubtful cases the lighter structure is chosen and strengthened if this is found to be necessary on test.

6.2. Structural Test Department

Early in the design stage a programme of test work should be prepared. Besides the panel tests referred to previously, this will include tests of detail structural joints, such as main wing joints, and all tests of completed components. Design of rigs for fuselage and wing test should be put in hand at an early date as, on a large aircraft, these assume major proportions.

All Class I castings and forgings must be tested to cover the requirements and one extra item should be ordered for this purpose.

As the design proceeds many development tests will be required such as on windows, floors, seats and so on, and rigs for the testing of hydraulic systems and power controls will also be required. On main structures, such as wings, repeated loading up to, say, 40 per cent of the ultimate condition applied several thousand times will show up weaknesses in the design which would not

be evident on a test taken only to proof and ultimate.

All ultimate pressure tests on fuselage shells should be done under water in order to avoid catastrophic failure, resulting in a costly repair or even a complete replacement of the specimen. A problem when testing modern aircraft is the simultaneous application of pressure and gravity loads. It is essential, however, that this be done if the test is to be representative.

6.3. Altitude chamber

With the advent of high altitude aircraft with pressure cabins, an altitude chamber is essential. This should not be too elaborate, but even in its simplest form it is a costly item to run and care should be taken that it is not used unnecessarily. Its main uses will be to check pressure cabin controllers, safety valves and shut-off valves and to check the functioning of these items in a complete shell in the form of specimen flights at altitude with pressure and temperature represented. A further use will be to check the functioning of electrical, hydraulic and mechanical devices under conditions of low pressure and temperature.

7. AERODYNAMICS DEPARTMENT

As mentioned in the introduction to this paper, it is not intended to deal so much with the aerodynamic design of the aircraft, as with that part of the aerodynamic work which directly affects the design and stress department. It must be pointed out, however, that a great deal of work has been done by the aerodynamics department before the General Arrangement stage has been reached. This will involve: estimation of weight and C.G., wind tunnel model work, performance estimates, stability and the investigation of operating costs. All this work must be carefully co-ordinated, in order to ensure that the final result will produce an aircraft which is a reasonable step forward and that it is being done in the right way.

When the G.A. has been settled in principle, information should be issued as soon as possible roughly in the following order, to enable the stress and drawing office to proceed: Information for balance-out calculation, chordwise and spanwise load gradings, suctions and pressures applied to various parts of the structure. The stress office will require this information.

The drawing office will also require the following information: Wing sections, flap data, hinge moments, angular movements and tab data for the design of the control surfaces. Information of a thermodynamic nature will also be required such as, temperatures and flows in anti-icing ducts, cabin air conditioning and heat exchanges.

7.1. Weight control

This section is of relatively recent origin but is found to be absolutely essential in order to avoid the weight creeping up as the design proceeds. The work of the weights control department, so far as this paper is concerned, consists in breaking down the whole aircraft into sections and listing them in a weights book, which is then circulated to the various senior designers in charge of the particular units. The estimated weights are then recorded against each item to make up the all-up weight of the aircraft and periodically, say once every two weeks, these estimated weights are brought up to date as the design proceeds, first from the rough scheme, then from the finished drawings and finally from the actual weighed items.

It is the duty of the weight control department to bring to the attention of the senior designers any weight increases found and it is then up to the designer concerned to do something about it. A check on the movement of the C.G. of the aircraft also is kept.

It is quite surprising how close to the original estimates the weight can be kept, in fact on several recent aircraft the all-up weight of the aircraft came out to within under two per cent. of the original estimated weight.

7.2. Flight test

Before the prototype has flown a general programme of flight testing should be prepared in conjunction with the chief designer and the aerodynamics department. It is important to obtain as early as possible a general overall picture of the capabilities of the aircraft, rather than to spend hours of test flying in obtaining academic data, for useful as this may be, it can be obtained at a later date. The important thing during the early test flying is to keep the aircraft in the air. Small snags which do not prevent the aircraft flying should not be put right immediately, but listed and done when the aircraft has to come in for an essential modification.

Assuming no major snags, and with good organisation, the aim should be to average about one hour's flying a day for the first 100 hours of test flying. Any important snags found during the test flying should be reported immediately, and if a good night shift is provided, these snags can be dealt with overnight.

It is the responsibility of the flight test department, in conjunction with the aerodynamics department, to prepare detail flight programmes, to which the test pilot works, and to organise flight observers and instrumentation to record the results obtained. These will be written up and passed to the aerodynamics department. Loading sheets also must be prepared and these should be passed to the flight hangar without delay.

7.3. Instrument laboratory

With the advent of the modern high-speed, high altitude aircraft with its complexity of gear, the instrumentation of the prototype presents a job of major importance. Fairly early in the design stage, it must be decided what instrumentation is required and the various pressure points and thermocouples with their pipes and wires must be built into the prototype from the start and an automatic observer must be designed. This work must not be left to be done as an afterthought.

Strain gauging, both in the air and on the ground, has become an essential part of prototype testing and the instrument laboratory should be responsible for the special gear required.

It is most important that all recording gear be thoroughly tested before it is installed in the prototype, otherwise serious delays will result in the test flying.

8. DEVELOPMENT ENGINEER AND TECHNICAL BUYING DEPARTMENT

The importance of this department in getting a prototype out quickly cannot be over-emphasised. On its efficient working depends the avoidance of long delays in obtaining materials and proprietary equipment.

Delivery dates of six months or more are often quoted for special materials. This cannot be tolerated and it is surprising what can be done to improve on these dates by bringing pressure to bear on the supplier, and refusing to take "no" for an answer. In these days it does not follow that because an item is quoted in the data sheets it is necessarily readily obtainable and to assume this can cause long hold-ups in the shops. As soon as a designer knows from his schemes what materials, forgings, castings, ball bearings and, in fact, any bought-out articles he will require, he should at once issue an advance order for these to the technical buying department.

Apart from the ordering of materials and standard items, it is the responsibility of the development engineer to deal with the supply and development of equipment specially designed for the particular aircraft and to deal with such matters as price, delivery, and so on. In order to be able to do this, he must be a first-class experienced engineer.

Inventions and innovations are constantly being submitted to the firm. Many of these are of no interest, impracticable or frankly frivolous and the designer's time should not be wasted examining them. It is the development engineer's job to vet them and pass on only those which appear reasonable.

9. THE EXPERIMENTAL SHOP

The experimental shop should be a self-contained organisation complete in itself, with its own jig and tool department, machine shop, fitting shop, sheet metal shop and planning department. It should in no way be under the control of the main production shop, but may be complementary to it in that some of the jigs, tools and layouts which were used to build the prototype may be handed over after they are no longer required for the prototype. Some jobs of a more specialised nature, such as drop hammer and stretcher press work, cannot be undertaken in the experimental shop and then the assistance of the production shop must be sought.

It is most important that all errors, however small, found in the drawings be reported immediately to the drawing office. Experimental shop foremen and charge hands are rather apt to put obvious mistakes right on their own initiative and say nothing about it, with the result that the error is found again on production, when it will entail a costly modification.

Production can be assisted if some of the production foremen and charge hands are seconded to the experimental shop to work

on the prototype in the early stages, since they are then familiar with the job when production is started. The personnel of the experimental shop should have a gift for improvisation and not be content to hold up the job until all the information is available.

The experimental shop should have its own stores, independent of the main works. These stores, apart from materials, should include machine tools, such as rivet guns and power drills, milling cutters and so on.

A progress engineer should be permanently attached to each main section of the shop. It is his job to co-ordinate the work in that section and to see that the right bit is in the right place at the right time. This man should be able to cope with about 50 orders at one time and must bring up any potential bottleneck at a weekly meeting held by the experimental shop superintendent, with the chief methods engineer, shop foreman and chief inspector present. Any points which are brought up at this meeting which cannot be settled there should be brought up at the fortnightly meeting referred to previously.

9.1. Mock-up

It is not always realised that mock-ups can be very costly items and great care must be exercised when deciding what type of mock-up should be built. A point that has to be decided is, whether to build, first a very rough mock-up in order to obtain a general idea of the aircraft, followed by an accurate mock-up built from the actual drawings with all the structure represented, or whether to build one mock-up only, from the best available information at the time and to modify this as the design proceeds. In the first case pipe templates, and so on, can be taken off the accurate mock-up and control runs can be represented; this saves time on the prototype.

In the author's view, the first type should be used for the smaller aircraft and the second type for large aircraft, provided that certain sections, as for example the engine installation, are mocked up accurately, if necessary as a separate mock-up.

A mock-up of the complete aircraft showing wings and tail should not be built. This is a waste of time and money. The location of the mock-up is important. Ideally it should be positioned facing large doors or windows so that a distant view may be had from the cockpit. It is most misleading when trying to assess the view to look at a blank wall. Everything in the cockpit should obviously be shown, even to the smallest items, and wherever possible the actual equipment should be used. Paper dials representing instruments are useless.

The type of man required to work on mock-up should be versatile and capable of doing a job quickly, when necessary to verbal instructions or very rough sketches from the drawing office; he must have a knack for doing a job with just the right balance of accuracy and speed. He must not be considered as a man who is not good enough to work on the aircraft and is therefore put into the mock-up shop.

9.2. Methods engineers

As soon as a drawing is issued it should be examined by the Methods engineer in charge of the particular unit, who will decide what jigging is necessary and will pass this information to the jig department so that the design of the jigs may be started. He will also decide what special materials and bought-out items are required and if these are not already in stock will place an order on the technical buying department for them. A layout of the method of doing the job should then be prepared and one copy given to the production department for early information. Each layout should have its own file and be brought up to date each time the drawing is re-issued.

9.3. Jigging and tooling

Jig design for prototype work has become a highly specialised subject and there are obviously many ways of building them. Space, unfortunately, does not permit a detailed discussion of the subject here, and one can only mention that a good compromise must be struck between cheapness, time to build, flexibility of use and adaptability for production. Tools, made in compressed wood or zinc, for rubber press work should be made in the experimental shop from the loft printer plates. These parts should then be pressed by the production shop and returned to the experimental shop for correction, before the tools are finally handed over to production. As mentioned previously drop hammer and stretcher press tools, being of a more specialised nature, should be made by the production department.

9.4. Erecting shop and flight hangar

At a very early stage of the project the erecting shop should be laid out to ensure that the prototype during erection is in the most convenient position for the assembly of the main components. Overhead lifting tackle, flush weighbridges and points for power tools and lights should be built into the hangar. Mobile scaffolding, working platforms and, in fact, any items of ground equipment which facilitate the erection of the aircraft should also be designed at an early stage.

9.5. Inspection

The chief inspector should be responsible for all inspection, that is during manufacture of detail parts, erection and test flying. Responsible to him, apart from the detail parts inspection, should be five senior inspectors in charge of the following sections: Jigging, structural, hydraulic, electric and one overall inspector with a roving commission.

These permanent inspectors should see the job right through from the original erection to the completion of test flying. They must all be trained engineers and be able to understand the implication of any snags they may find and able to express a balanced and reasonable opinion upon them.

CONCLUSION

The author has attempted in this paper to present an overall picture of the factors which, in his opinion, govern the efficient producing of a prototype aircraft and has tried to stress the important points. This embraces a wide field and in order to cover all of it, the author has had to be brief. Many of the headings would justify a paper to themselves.

Good organisation, important as it is, goes only a certain way to achieve the desired end, and to the author the most potent factors are still: Getting the right men for the job, enthusiasm, and above all, hard work.

DISCUSSION

G. R. Edwards (Chief Designer, Vickers-Armstrongs Ltd. (Weybridge), *Fellow*): It was right to build production aeroplanes from the start and not to make the first one a prototype, except when the aircraft itself was being used as a research vehicle to assist in the perfection of a subsequent design. But before a production aircraft could be built it was necessary either to have a production order, or to be fairly certain that one would be forthcoming. To lay down a production line of a modern aeroplane without having an actual order called for a great deal of courage, and even more money.

The thing to do in the first instance was to be sure of the production series. How that was consistent with orders for two or more prototypes being placed with different firms, he was not sure, because that would mean two production series of two different aeroplanes and, so far as could be gathered from the national Press during the past few weeks, there were not enough production orders for one sort of aeroplane, let alone two sorts. Thus it seemed that the problem was not to decide to make the first of the production order a prototype, but to get a production order.

He did not agree that the experimental shop should be under the control of the chief designer. There was a possibility in any organisation that the various personalities might not mix and that they might reach a state of some disagreement as to the way in which the experimental shop was run; but he felt that the chief designer had to make sure that all the other executives at his level were suitably trained and that they agreed with him about the experimental shop. That was a much more satisfactory arrangement.

On what type of tooling would Mr. Wilkins build his first prototype when it was one of a production batch; would he build it by what were known popularly as "knife and fork" methods, in which the assembly jigs in particular were temporary, being made out of pieces of scaffolding, old iron, and so on, or would he delay the prototype sufficiently so that it could be built on the first set of production assembly fixtures? There had been many arguments over the merits

and demerits of the two schemes, and he knew very clearly his own feelings. Did Mr. Wilkins think it right to hold up the first prototype so that it could be built on production tools, and particularly the production assembly fixtures?

He was surprised that Mr. Wilkins thought the weight control came under the aerodynamics section of the design office; he had thought that the general practice was to put it into the care of the structures group.

Would Mr. Wilkins enlarge on the actual duties of the development engineer and the technical buyer? He did not recognise anybody in his own organisation who did what he believed either of those two people were meant to do.

He fully agreed about organisations being built to suit individuals, and not *vice versa.*

It was time they began to "blow the trumpet" of the design profession; Mr. Wilkins was right about the application of the term "draughtsman" to all and sundry. There were people in drawing offices who were called draughtsmen, but who were far more qualified as engineers than were 95 per cent. of the people who went about the country calling themselves engineers.

He did not agree that the stress office, the aerodynamics department, and so on, should each be suitably fenced in. If possible, all the people concerned should be in one big office. Physical walls around the stress office, the aerodynamics office, and so on, could become mental walls. He appreciated the significance of team work, but he urged that the significance of the overall team was more important than that of the individual team.

He agreed about overtime, and getting the job done quickly. The men in the drawing office could work overtime, and they were none the worse for it. But overtime work must be employed efficiently; the right course was to give the job a first class project first so that the major engineering problems were resolved before it went into the drawing office, and thus avoid demoralising redesign.

The specialists should "have a go" at the aeroplane in the early project stage. All specialists tried to lead chief designers up the garden, which was fairly easy, for chief designers were simple folk! But one method of dealing with the wireless and electrical "kings," who were the chief offenders in the "garden-leading act," was to learn the reference numbers of some of the wireless sets, such as TR681, and ask where they were to go. The offending experts would become quite certain that the chief designer had taken a correspondence course in radio and the "wool pulling" would become much less pronounced!

D. L. Hollis-Williams (Fairey Aviation Co. Ltd., *Fellow*): He regretted that Mr. Wilkins had not completed the picture by bringing in all the preliminary stages—design study, negotiation work, and so on—all of which could occupy as much time as designing and building the aeroplane.

From the design side firms seemed to be converging in the methods used. The differences that were apparent some time ago were now much less noticeable, and although functions might be described by different names and responsibilities might have rather different definitions, they all seemed to be doing a difficult job in the same sort of general way, trying to ensure order where chaos could so easily be waiting just around the corner. That was probably the result of economic pressure over the years. The costs of aircraft had become greater and greater; it was usually found that the estimate had been overspent and efforts were made to increase efficiency by spreading the load differently and as a result, the present method of doing things had been evolved.

There were two schools of thought on the building side. There was the procedure advocated by Mr. Wilkins' company and some others, of rushing the prototype through at all costs, getting it into the air and getting through the flight development. The other school held that it was much better to do the job more on production lines—for aircraft to be used for military or civil purposes, not research aircraft—so that, if production did ensue the prototype constructors, having done the job once, had not to use so much energy in going over the ground again and making things ready for production. His own firm was rather inclined towards the second method, believing that it was not too expensive in either time or money; one important advantage was that a symmetrical aeroplane was obtained with which to start prototype trials, which gave a good start to development. In the past his firm had spent much time in getting over the effects of asymmetry which had been built into the aircraft by short-cut methods, which

led to delay before real progress could be made with flight development.

All firms were striving in the same direction to secure greater efficiency, but there was always the problem of discontinuity. When a firm had built up a large and powerful design staff, it was a matter for anxiety if there were not a follow-on programme, for they could not expect to get efficiency out of a design staff or an experimental shop staff if those people knew that, by putting forward their full effort, they were working themselves out of a job. By improvements in organisation and method, small percentage effects could be achieved here and there leading to increased efficiency; but the overwhelming factor controlling efficiency was continuity of design and development.

S. Camm (Chief Designer, Hawker Aircraft Ltd., *Fellow*): The statement in the third paragraph of Section 2 of the paper, that "The skill of a Company can be measured by its success in judging the size of the step in design which should be taken," was vital.

The exhortation that periodically the designer should stand back and ask himself whether everything incorporated in the design was really necessary, was something that might be done almost every day, and this critical outlook might be applied not only to items of equipment, but also to the small details of construction. One of his colleagues on the Board of his Company always urged that there should never be three rivets where two would do.

He disagreed with the author's statement that if the experimental department could build the aircraft from the drawings, so could the production department, provided that every item was dimensioned correctly and had a part number. The methods were not necessarily the same; a part might be machined from the solid experimentally, but the forging would be used in production, and that would mean a very different set of drawings. Often the methods used for a prototype were the opposite of those used in production. The production people must be given a good set of drawings at the start. Certainly this should be the case where an order, say, for military aeroplanes of reasonable size was received. For a civil aeroplane in which the ultimate market might be doubtful, there was possibly a case for a less exacting system of drawing procedure.

B. Stephenson (Assistant Chief Designer, Vickers-Armstrongs Ltd.): The production line moving forward concurrently with the prototype was the only way in which to avoid considerable delay, but he could not reconcile the production line being built to experimental drawings if those were subsequently to be broken down into production form. Good drawings were necessary from the beginning. The production people should be brought in from the earliest conception, the drawings should be made fundamentally for production and concessions given for prototype work; the experimental shop, having simpler jigs and tools and not fully tooling up, could work better to production drawings than the production people could work to experimental drawings. If the production line were to move with the prototype an important inference was that the customer knew what he wanted before he got it, but that was very rare.

From the moment the prototype was launched into the drawing office it was essential to get it under way, and one of the best mean ways was to settle the geometry as early as possible. That might appear to be a very detailed point; but if the geometry were settled early the mould loft could get started, the first mock-up could be the last mock-up and yet could be modified as desired. The feeling was created that the job was being done and the atmosphere was right for inspiration, which was essential. Inspiration would not come to order, but had to germinate, and it germinated best when a job was under way. A relatively easy job helped the close thinking necessary to build up in the proper order.

There should be no checking of drawings; the responsibility should be clearly with the man who had drawn the part or with the man for whom he worked. That practice paid dividends every time. If a man made too many mistakes he would probably have to look for another job.

Specialists should be duplicated, if the Company could afford it. If there were only one of a particular kind of specialist, and if he were knocked over by a bus, for example, things might be awkward. Two specialists could usefully be employed; they could create competition, which was necessary, and yet they could work together when a job assumed big proportions.

Simplicity, which was most difficult to achieve, could not be over-emphasised. The self-criticism which Mr. Wilkins suggested was very necessary; when everything had

been omitted which need not go in, adopting the policy "When in doubt, leave it out," the question should be asked, was it worth the cost?

S. Scott Hall (D.G.T.D.(A) Ministry of Supply, *Fellow*): Unfortunately, this world was not ideal from the engineering point of view, and any decision on the length of step which had to be taken to the next breed of military aircraft obviously depended on many considerations outside purely technical ones. One of the most important was the question of money. It had to be decided how much money was available to be spread over a programme covering a period of years. The Ministry endeavoured to obtain from the aircraft designers themselves an opinion as to what was feasible to attempt. There was a system of seeking design studies, and if the Air and Naval Staffs should call for something which was really beyond the bounds of practicability, the designers had the chance to come forward and demonstrate that it could not be achieved.

But there was nothing haphazard about the business. Indeed, there had been complaints of delays due to the months of discussion with the staffs in the weighing of the various factors, which had to take place; it was a matter of seeking the best compromise between all the conflicting factors.

He thought that they had now reached a stage in the development of aviation at which they should be able to rely on the ability of any given firm to produce a reasonably successful prototype to a given specification, and should now leave behind the dark middle ages of aviation when, because it was so uncertain whether a prototype would be successful, even in the most elementary sense, it had been necessary to go to two or three firms and order rival aircraft. Nevertheless, it was still necessary to balance up what was wasted in effort against what was gained by the element of competition, and that was still a debatable question. What did Mr. Wilkins think of the value of competition?

F. A. Kerry (Saunders-Roe Ltd., *Associate Fellow*): He was surprised in Fig. 1 at the relatively large number of drawing boards being used for each of the prototype aircraft at the time the first flight was made. There was no falling off in the number of draughtsmen employed towards the end, as would be expected. That indicated that the first flight in each case had taken place a considerable time before the design was completed, *i.e.*, the design as a whole; obviously the structural part must have been completed. There was no period during which the later drawings were being sent to the shops before the machines were flown. Could Mr. Wilkins state approximately the percentage of the design which was complete at the times the various machines flew? Was it the same in each case?

Standardisation should be restricted to the smaller items. Often, if they tried to use the larger standardised parts, the customer would say that he would not have them and they had to start again.

He disagreed that the stress office should supply to the design department low load figures for the structure; if the designers knew that the load figures that were being passed out to them were on the low side they would make too much allowance. There must be complete confidence between stress office and designers.

Particularly for large aircraft, outside specialists must be called in. The general scheming should be done by the aircraft manufacturer's designers, the advice of the specialist firms should be obtained and studied, and those firms should be asked to do the detailed design and the production of the specialised parts. For example, no one would expect an aircraft manufacturer to design an electric motor; the same policy should apply to other specialised parts in modern aircraft.

W. S. Hollyhock (Hawker Aircraft Ltd., *Associate Fellow*): The policy of placing modifications on the production line to keep that line going sounded very nice and theoretically it was unassailable as an argument, but unfortunately it never stopped at that. There was always a certain percentage of work which had to be undone and redone. The argument at the time was that probably 90 per cent. of the work would be all right and perhaps half of the remaining 10 per cent. would not have to be scrapped. But on the day of reckoning, when the tools and the parts had to be scrapped, the view was not so sympathetic; questions were asked and there were doubts as to whether the method was the right one after all.

He favoured the minimum amount of overtime consistent with high rate of output, in order to maintain the enthusiasm of the staff. The days had passed when aircraft production was the business only of enthusiastic

young men; it was now a job of work pure and simple, although enthusiasm was necessary. The working of overtime was basically an admission of weakness, not necessarily avoidable, and the hours of work should be fixed as the normal hours, and overtime should be worked only on really urgent jobs. In those circumstances, work all night if necessary, but stop it as soon as the particular urgent job was done. He disagreed particularly that if one section were working overtime, the whole office should do so, because then everybody became stale and production lagged.

The experimental department was so much a part of the design unit that if it were not under the control of the chief designer there would not be continuity of effort.

The movement of men between firms was probably a good thing, from the points of view of both the men and the firms. Restricted conditions tended towards a lowering of the standard of design and towards lack of flexibility and of the broad outlook.

If the specialist firms were not allowed a certain amount of say, there would be no specialised knowledge upon which to draw.

All draughtsmen were, or should be, regarded as designers; the only difference between the really senior men and the drawers of lines was a matter of experience, age and ability. It would be unfortunate if it came to be thought that the way to the chief designer's office did not pass through the drawing office, for in that case drawing offices would not recruit the best type of men.

N. E. Rowe (British European Airways, *Fellow*) *contributed*: He had always thought that to standardise things which might have a significant bearing on the design of an aircraft as a whole—and that might mean quite small items at this stage of rapid development of the art—was the reverse of a service to the aeronautical interest. As the lecturer said, it was so difficult for the designer to srike the exact balance of conflicting requirements that as many limitations in this field as possible should be avoided.

He thought that the testing of major components at the aircraft firm, as the lecturer said "so that both the designers and stressmen can watch the test in progress and reap the benefits of visual observation instead of by reading a report," was true, also of many other aspects of the use of apparatus to obtain data, a notable one being the wind tunnel. He had thought that one advantage of having this equipment at the firm was that it ensured recruitment of staff, who would not otherwise be employed by them, and this in turn gave a much wider basis to the firm's interests and knowledge.

He thought the author's belief that the experimental shop should come under the chief designer and should be a self-contained organisation was a "bone of contention" and that it must depend on the overall organisation of the firm as to which method was used, although in the author's firm it seemed to work well. The point that some of the production foremen and chargehands should be seconded to the experimental shop to work on the prototype in the early stages was a very good one. Was this the method adopted by Mr. Wilkins' firm?

C. G. W. Ebbutt (Heston Aircraft Co. Ltd., *Associate Fellow*) *contributed*: He disagreed about overtime worked in the drawing office and design department generally on prototype drawings. No overtime whatever should be worked until the point was reached where an urge was necessary to rejuvenate the job. Then all the overtime possible should be worked, including week-ends if necessary, for a relatively short period, say one month. By doing this they got the advantage of the general momentum carry-over to see them through and at the end of that time that was just about worn out—and so were the draughtsmen.

He had found some evidence that the use of die stampings in a prototype could be made to pay, provided that a certain minimum number of prototypes or pre-production aircraft were ordered in the first instance. What were the lecturer's ideas on this, and roughly how many aircraft were needed to cover the cost of tools?

MR. WILKINS' REPLY

Mr. Edwards: His point about the production order really was, could the country afford to give orders to more than one firm to produce the same type of aeroplane, or should it not have sufficient confidence in the project, if it did not represent too great a step forward, and give it to a firm which could be trusted to make a job of it? The Comet was a reasonable step forward in design, and the firm went straight into production concurrently with the prototype. Whether or not that could be done with military aircraft he was not prepared to say. But could the country afford to give the same

job to three or four firms? If the design represented too great a step forward it should be treated as a research aircraft and be made perhaps half-scale, or in a cheaper way than it would be in full production.

As to the experimental shop being under the control of the chief designer, he did not think that his particular chief designer worried himself too much as to whether or not some people were getting too much bonus, or something of that sort. He had a competent manager who saw the shop stewards periodically, and discussed such matters as the heating or lighting not being right, or the floor being damp, or whatever they talked about. If there were any sort of trouble which the manager of the shop could not settle, it would be brought to the attention of the chief designer, who was the arbitrator and, as a director of the Company, could do something about it. The organisation had been built up in this way and it was found to work well.

The reason why the weight control came under the aerodynamics section, he believed, was that, when it was introduced, the stress office was too busy to cope with it, so that it had just happened, as was so often the case. Perhaps, also, it was because the aerodynamics section wanted to know that the C.G. was reasonably near the front and not, as so often happened, towards the back.

The tooling for the production aircraft should certainly not hold up the prototype; if the production people could not use the prototype tools there should be a new set of tools. Time was the all-important factor in getting the prototype out, and nothing should stand in its way.

His Company had a particularly good development engineer. If any piece of equipment were required quickly they could obtain from him information on advance delivery dates, and so on. He also advised the equipment people of the tests required, and matters of that sort, and seemed to be able to get things from the suppliers quickly. He could probably get castings and forgings and other special materials rather more quickly than most people; he believed that his Company was envied a little in that respect. The development engineer was invaluable and they could not do without him.

Mr. Hollis-Williams: He could not go into the earlier stages of the work because his time was limited; he would have liked to have said more about it, but Mr. Edwards had dealt with it in his paper—and he was told not to overlap that paper too much!

Perhaps the reason why the various firms were drifting into the same methods of doing things was that various people in the Industry moved around and the ideas of one firm would stick to them when they moved to another.

Ideally an aeroplane should not be built at all if there were no production order, unless the aircraft concerned was purely for research purposes. That was a difficult matter. His Company had had production orders for all the aeroplanes referred to in Fig. 1. Where they had not at first obtained production orders they had made production orders. For example, when they were building the Dove, they had decided that they would sell aeroplanes to that design when produced. In other words, a firm should not start on a prototype until they were prepared to go into production; if nobody would buy the aircraft before they were built, then it was anticipated that they would buy them afterwards because the Company had explored the market and were confident that sales would result.

A lot of the continuity achieved by his Company had been of their own making. For example, the Mosquito was a private venture suggested by themselves; nobody had asked for it. The Venom and the Heron were also the results of suggestions by the Company. The practice was to go ahead and build a machine, hoping it would be wanted. If a firm were prepared to take the risk, continuity of design could be assured.

Mr. Camm: He had meant that prototype drawings should not be absolutely complete; questions of armament and other things were involved. He was referring to a reasonable standard of drawings, but not necessarily those broken down into sub-assemblies. In his experience, whenever he had tried to be clever and to assemble things in a certain way the production engineers would say that that was not the way they wanted it and the job would then have to be redrawn. If the information could be pushed out quickly to the experimental shop, and if the production engineers came to the drawing office so that each side could discuss how the job was to be broken down, each side should get what it wanted. The production people would see the original prototype drawings and could indicate how they wanted various things

done, leaving the experimental drawing office to get out the further drawings as quickly as possible, without being bothered too much with production breakdown.

Mr. Stephenson: He was keen to get the geometry out quickly, but felt that if this were done too soon they would find that they were committed to certain features which ought to be changed but would be too costly.

When he was at Vickers-Armstrongs Ltd. in his early days of aviation, there was a man who checked literally every layout. If he had a detail drawing to check, he would either demand to see the draughtsmen's layouts or, if they were not available, he would lay out the job for himself. That practice was impossible where a job was required quickly. At de Havilland's there was a man who knew what to look for on a drawing, whether anything was drawn to half-scale, and so on, and he picked up an enormous number of points, so that drawing re-issues were kept to a minimum. He agreed that the designers themselves should be responsible for the correct dimensions of their own drawings.

He considered that one specialist was quite enough, or even more than enough, but he appreciated Mr. Stephenson's point.

Mr. Scott-Hall: He was concerned as to whether, in the country's present parlous state, they could afford the luxury of competition. When the Ministry had to spend *x* million pounds on a project an "insurance" aircraft might be desirable, but he did not think it could be afforded; they had to put faith in (*a*) the project, and (*b*) the firm receiving the order, and be reasonably certain that the project would be a success. Also if more than one firm were in competition, then the decision as to which aircraft to order could not be taken until the last one had been flown and tested, thereby causing still further delay in starting production. The forward step must not be too great; if it were, then the project should be purely a research aircraft.

Mr. Kerry: If the curves showing the number of drawing boards still employed at the time of the first flight of each of the aircraft listed in Fig. 1 were continued it would be found that they would not have dropped much more, because after the prototype flight it was still necessary for various people to be engaged on the work in order to keep the aircraft going in production. That rather confirmed his earlier statement that the drawings that were produced for the prototype still required much work on them to suit production; the curves would drift on at practically the level at which they finished in Fig. 1 for at least as long as was required to deal with the prototype. One day he might extend such a curve just to see where it did go, but there were still people working on the Tiger Moth!

The question of reduced loads supplied by the stress office was a purely practical point, as in the past it had been found that everyone put a bit on for luck and tests of complete components were coming out over strength. By supplying reduced loads from the stress office that state of affairs had been corrected.

Some aircraft manufacturers farmed out complete undercarriages to some of the excellent specialist firms, who were informed of the design data and were told where an undercarriage had to be hooked on, that it had to fit into a certain hole, and so on. In that way the aircraft manufacturers saved themselves a great deal of trouble. But he did not think they obtained the best results in that way. The aircraft manufacturers, as the parent firm, should design as much as they possibly could, discussing the matter from the beginning with the specialist firm; the latter must be willing and co-operative, they must not say that the matter was one for specialists and that the parent firm must keep out of the way; there must be co-operation from both directions. The main responsibility for any failure must rest with the parent firm; there must be no alibi, no claim that they were let down by the specialist firm; they must keep a sufficiently close watch on the design and manufacture of the equipment to be able to take responsibility for it. That was a controversial point, as shown by the fact that individual firms tackled the job in different ways.

Mr. Hollyhock: Obviously there must be a system of suspense notes which were issued for any parts that were doubtful; if a feature were largely experimental, or if they did not think it would work, or had never handled it before, a suspense note would be issued for it and then it was not made on the production line.

Overtime was a vexed problem, but he believed that the fact that overtime was being worked tended to stimulate enthusiasm, provided that it was not overdone, and that

if people were not working overtime, although the job was urgent, they would feel that it was not and would tend to lean back. All prototypes were urgent and logically overtime should be worked on them. He agreed that aircraft development nowadays was not just a game for enthusiastic young men.

It was good for men to move from firm to firm when they were young. When a firm had built up a successful design team of reliable men who could work as a team, it would be foolish indeed to allow any member of the team to leave, but the junior members of the staff should certainly move around as much as they could.

He did not intend to suggest that the specialist firms should have no say whatever about equipment. They should have every say, but they should not "keep anything under their hats;" they should come out into the open and discuss the problems as much as possible—depending on the parent Company's intelligence! At least they should explain what they were trying to do, and should not take the attitude that it was their job and that the parent Company must keep away.

He did not think a man could be a chief designer if he had not served in the drawing office, and for a good many years. It was the only route to the chief designer's office.

AN EXPERIMENT IN FLYING TRAINING

by

A. C. W. RATTLE, A.F.R.Ae.S.

LATE in 1947, at the instigation of the members of the Project Office of Short Brothers Ltd. of Rochester, an approach was made to the management of that Company on the subject of subsidised flying training for employees. Enthusiasm, unlike funds, was not lacking and the proposal was sympathetically received by the management, who agreed to make flight training to "A" licence standard available at one pound per hour, pre-1939 rates. The necessary apparel, including helmets and goggles, were supplied on loan, and training began at the Rochester Flying Club on Tiger Moth aircraft which were later supplemented by Magister and Auster types.

A few weeks after the introduction of the scheme, it was suggested to the author that ordinary daytime flying instruction, although it was standard procedure, left instrument flying under natural conditions to be done later, when reasonable proficiency had been attained under normal visual conditions. Further, a reasonable period for conversion was necessary when undertaking night flying after some daytime solo practice.

In the light of this, an experiment was proposed by Wing Commander Lindsay, Chief Flying Instructor, and Mr. C. Dash, of the Club. What would be the result of doing *ab initio* training at night, and accustoming the pupil to basic instrument practice from the outset? It was felt that in a given time, a higher standard of proficiency would be attained by the average pupil and that conversion in the reverse sense, that is from night flying to day flying, would be accomplished in a shorter period.

The author agreed to be the experimental pupil, having flown only as a passenger previously and having no piloting experience. To make clear the conditions under which this flying was done, Fig. 1 shows a sketch map of the aerodrome. It will be seen that the advantage of almost unlimited space was not to be enjoyed: this factor in itself probably favours the pupil ultimately, since his approach judgment is keenly developed from the start. A personal log was kept during the training and extracts from this, together with comments, show how the experiment progressed.

Night flying training began during the evening of 2nd January 1948. The first flight was intended to test reactions generally, since conditions were extremely bumpy because of a high wind. The machine was taxied to the downwind end of the flare path, steering to pass between two red lights at the end of the row of flares. The flares were of the goose-necked paraffin type, and the actual flare-path was 450 yards in length. Straight and level courses were flown (so far as turbulence allowed!). The principal lesson learned was to locate the aerodrome at the apex of a triangle of sodium lights, formed by the three main roads. Once this point had been seen the eye immediately discerned the flare path.

5th January. Take-off was done without difficulty during this lesson. An advantage to the embryo pilot at this early stage is a line of flares, which materially assist in maintaining a straight course during the ground run.

8th January. This lesson was devoted to "circuits and bumps," and the necessity of allowing a sufficiently long approach was made clear, to provide ample time in which to align the aircraft on to the flare path. Several instructed landings were made; the light from the flares and the downward recognition light on the underside of the fuselage giving adequate ground illumination.

14th January. Excessive swing correction at the beginning of this lesson seemed to indicate that instructional sessions should be

Paper received March 1950.

Mr. Rattle is a member of the Design Staff of Saunders-Roe Ltd.

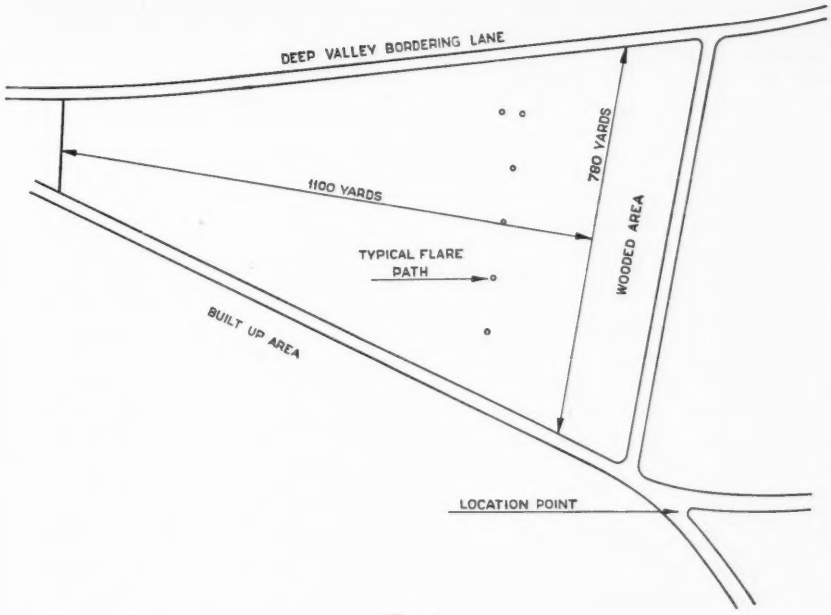

Fig. 1.

fairly frequent, otherwise nervous tension is apt to build up in the intervening period. Stalling instruction was given and further take-off and landing practice.

The total time flown by then was three hours and forty minutes.

15*th January*. Emphasis was placed on the flying of a true course round the aerodrome at one thousand feet. (Setting the compass had preceded every flight so far.) If the take-off were made due west, the subsequent turns would be made to compass indications of south, east, north (the cross-wind leg of the circuit during which the glide would be started), and finally, west again. Every effort was made by the instructor to avoid the well-known "head in the office" tendency. The chief fault which came to light at this stage was the flying of too small a circuit, possibly because of over-concentration on the compass. This caused over-shooting, but practice proved the remedy.

19*th January*. Ordinary circuit flying continued, and the bottom needle of the turn and bank indicator was explained, particularly to assist in maintaining course immediately after take-off. Used in conjunction with any conspicuous light on the horizon no difficulty was experienced.

21*st January*. This particular session was discouraging, in so far as an inexplicable complex arose which had hitherto not shown itself. Before landing it is necessary to settle on to a straight approach path as early as possible. On this particular occasion the feeling persisted that the glide in was being made at an angle converging upon the flares. The result was over-use of the rudder and considerable over-shooting.

22*nd January*. Although the trouble of the previous evening was still present to a small degree, the log records that some improvement was made. This fault was not experienced again, and as with most faults, sufficient concentration on the part of the pupil overcame the difficulty.

4*th February*. The normal practice was continued during this session, and the log records that with earlier closing of the throttle after a wider circuit, the landing process was much simplified. Although the circuit was flown directionally by compass, the actual distances were judged by the lights on the ground; for example, the turn across-wind on the third leg of the circuit was made when the

pupil estimated that the port wing tip had crossed the boundary of the aerodrome. A considerable improvement in the actual landings was made on this occasion.

11*th February*. Hitherto, the average flying time for each lesson had been one hour. The conditions during this evening were quite good and the usual dual instruction procedure was followed for one hour and twenty minutes. At the end of this time the instructor left the front cockpit with a few words of advice on over-shoot procedure, if this should become necessary, and the first solo was made. A little apprehensive at first, the author soon settled down to enjoy the experience and no difficulty was encountered. The total dual flying time preceding the first solo was ten hours and forty minutes.

16*th February*. After one hour's dual instruction, two solo circuits were made separately.

18*th February*. Flying conditions for light aircraft were far from ideal. Dual instruction only was given, and course keeping by compass was the main subject, in conjunction with the turn and bank indicator. Northerly turning error and acceleration effects were also explained during this lesson, which brought the total dual flying time to twelve hours and fifteen minutes.

Sufficient evidence, it is hoped, has been given to show that *ab initio* training by night has no major snags: on the contrary it would appear to have certain advantages. After the 18th February, the amount of solo flying by night was gradually increased, involving practice which eventually led to the tests for the "A" Licence being made successfully.

Conversion to daytime flying began on 10th April. A slightly inaccurate interpretation of wind direction, indicated by a drogue, was the only correction made by the instructor. Twenty minutes' dual, consisting of two circuits, preceded the first solo by day, and the remainder of the period was devoted to solo practice.

It should be mentioned that landing technique at night required slight opening of the throttle immediately before touchdown. The aeroplane would be lowered on to its main wheels first, and the controls be held firmly neutral until the tailskid touched. For the first few solo flights by day this technique was retained, but in the second daytime lesson the three-point landing was made the rule, wherein the aeroplane is stalled on to the ground, engine off.

This simple conversion was really the end of the experiment, and it was considered by all concerned that the stated objects had been achieved. The time to the first solo was of the same order as that usually taken by day, and the change-over to day flying involved no difficulty, the pupil feeling that he was about to undertake something rather more simple than that to which he was accustomed.

The period reviewed covered seventeen hours and forty minutes of dual instruction, at the end of which much more experience had been gained than would ordinarily have been the case, in the same length of time.

There are fewer distractions to the embryo pilot at night. He is concerned with a row of lights, which largely decide for him how to conduct his circuit, from keeping straight during the take-off to correct into-wind alignment on the approach and landing. From the point of view of the type of aircraft employed, although the Tiger Moth is universally acclaimed as an excellent trainer, its successor, the Chipmunk, should prove even better especially from the point of view of comfort. The first Chipmunk-trained pupil flew solo after four hours and twenty minutes.

In the author's opinion, *ab initio* flying training at night offers the possibility of a reduction of training time and costs. For the rapid production of Service pilots, especially in an emergency, such savings could be of some importance but natural conditions could not apply since a flare-lit aerodrome would be out of the question. A feasible solution to this would be the adoption of the "Two-stage Amber" system in which night conditions can be simulated in the pupil's vision by means of tinted screens. This method has been, and is being, used successfully in the ordinary course of night flying training under artificial conditions for more advanced pupils.

The author acknowledges with thanks the permission of Wing Commander Chambers, Manager of the Rochester Flying Club, to submit this account.

NEW ZEALAND DIVISION

FIRST ANNUAL REPORT FOR YEAR ENDED 31st DEC. 1949

THE Council of the Royal Aeronautical Society by special resolution in September 1948 approved the establishment of a Division of the Society in New Zealand to become operative from 1st January 1949. The action of the Council has resulted in increased membership of the Society and in the establishment of a number of active and enthusiastic branches working under the guidance of members. This year will always remain one of the most important years in the history of the Society in New Zealand, not only because it marks the establishment of the New Zealand Division, but because it has witnessed a considerable impetus to the objects and aims of the Society in the Dominion.

As members are aware the Society has recently obtained a Royal Charter which necessarily involves alterations in the By-laws governing the Society. Until these are approved by the Privy Council and promulgated, the Divisional organisation and its rules of necessity will remain on a provisional basis. The same position applies to a reduced degree with regard to Branch Rules. The drawing up of these is a simpler matter since in many respects, for example, in financial affairs the Branches are entirely separate from the Division. The main problem with Branch Rules is to obtain some uniformity and in this direction it is expected that Rules for all Branches will be drawn up shortly and approved by the Divisional Council.

With the approval of the parent Council, the New Zealand Division has been run during the year by a Provisional Divisional Council elected by postal ballot of all members known to be resident in New Zealand.

THE DIVISIONAL COUNCIL 1949-50

PRESIDENT

Air Vice-Marshal Sir ARTHUR NEVILL, K.B.E., C.B.E., B.Sc., *Associate Fellow* (Wellington)

VICE-PRESIDENT

Professor T. D. J. LEECH, C.B.E., B.Sc., B.E., *Fellow* (Auckland)

SECRETARY

Mr. T. T. N. COLERIDGE, B.E., M.I.Mech.E., *Associate Fellow* (Wellington)

COUNCIL MEMBERS

Group Captain G. E. WATT, C.B.E., A.F.C., B.E., D.I.C., M.I.Mech.E., *Fellow* (Wellington)

Mr. E. A. GIBSON, O.B.E., A.M.I.C.E., *Associate Fellow* (Wellington)

Wing Commander G. CARTER, O.B.E., *Associate Fellow* (Wellington)

Wing Commander W. G. WOODWARD, O.B.E., B.E., *Associate* (Wellington)

Mr. A. W. DINGLE, *Associate Fellow* (Palmerston North)

Mr. H. F. T. ADAMS, M.A., A.M.I.Mech.E., *Associate Fellow* (Christchurch)

Mr. A. H. T. BRAZIER, *Associate* (Christchurch)

Auditor: Squadron Leader M. B. Furlong

Following a resolution of the Divisional Council on 8th March 1949, Branches were formed in Auckland, Palmerston North, Wellington and Christchurch. As with all Branches of the Royal Aeronautical Society membership is open to any persons interested in aeronautics irrespective of qualification for membership of the Society. The Divisional Council are well aware that it is the activities of the Branches which really constitute the life and work of the Society in New Zealand.

The Divisional Council therefore has felt most encouraged by the good work done by the Branches and the whole-hearted and enthusiastic support they have received. Details of the activities of each Branch are as follows:

AUCKLAND BRANCH

Chairman and Council Representative: Professor T. D. J. Leech (*Fellow*).
Honorary Secretary: T. Campbell-Allen (*Associate Fellow*).
(Mr. F. A. Reeves acted as secretary for the first part of the year.)
Executive Committee: F. H. Sorrell (*Associate*), A. J. Sanders, F. M. Thomas (*Associate Fellow*), B. G. de Bray (*Associate Fellow*), F. A. Reeves, D. A. Patterson.

Seven general meetings were held during the year, all of which were well attended, the average number being 67. The Branch membership is 99 including the Auckland Model Aero Club as a Corporate Member.

PALMERSTON NORTH BRANCH

Chairman and Council Representative: A. W. Dingle (*Associate Fellow*).
Secretary: F. E. O'Leary (*Associate*).
Executive Committee: F. G. C. Henwood (*Associate*), G. C. Ellis (*Associate*), C. T. B. Fitzgerald, A. W. N. Kitto (*Associate*), D. Smillie, R. J. Westcott .

Branch membership is 77 and four meetings and a visit to R.N.Z.A.F. Station, Ohakea, were organised during the year.

WELLINGTON BRANCH

Chairman: Air Vice-Marshal Sir Arthur Nevill (*Associate Fellow*).
Vice-Chairman and Council Representative: Wing Commander W. G. Woodward (*Associate Fellow*).
Secretary: A. F. Castle.
Executive Treasurer: F. Young.
Executive Council: Professor L. R. Richardson, J. D. Robins (*Associate*), R. J. Gibbs, K. H. Day, R. R. Roberts, N. Davis-Goff, J. B. Flynn (*Associate Fellow*).

Branch membership is 109 and four meetings were held during the year.

CANTERBURY BRANCH

Chairman and Council Representative: H. F. T. Adams (*Associate Fellow*).
Secretary: A. H. T. Brazier (*Associate Fellow*).
Executive Committee: F. Brooks (*Associate*), J. Palmer, G. Newton (*Associate*), I. Leigh, N. Mason, Professor R. Rastrick.

Four meetings were held. Towards the end of the year Mr. M. R. Roper replaced Mr. G. Newton, who was transferred to Wellington. The Branch membership is 35.

MEMBERSHIP

During the year the membership of the New Zealand Division has grown considerably. The number of members now on the New Zealand register is as follows:

Fellows	2
Associate Fellows ...	27
Associates	42
Graduates	3
	74

FINANCES

As shown by the financial statement the expenses of the Division have not been great and the financial position is healthy. The Divisional Council acknowledges gratefully the grant of £100 made by the Society from the New Zealand Branch portion of the accumulated funds of the Australian Branch. Half of each

subscription is by decision of the Council (of the Society) retained for the use of the New Zealand Division so that an assured and regular income is available. Although the expenses have not been much the Divisional Council is of the opinion that no special drawing on these funds should be made at the present time, as it is preferable to build up a substantial fund to allow future expansion as the best form of activity for the New Zealand Division is disclosed in the future.

A subject which has occupied the attention of the Divisional Council during the year has been that of recognition by the New Zealand Engineers' Registration Board of the technical qualifications of Fellowship or Associate Fellowship of the Society. Certain preliminary discussions have taken place with the Engineers' Registration Board with the object of securing the same degree of recognition as that accorded to technical members of the other British Institutions.

LIBRARY FACILITIES

The New Zealand Division receives from the Society three sets of the Society's Journals. Arrangements have been made for these to be housed in the libraries of:

The School of Engineering, Auckland University College, Auckland.
The New Zealand Institute of Engineers, The Terrace, Wellington.
The School of Engineering, Canterbury University College, Christchurch.

Arrangements have been made with these bodies whereby these journals are available for reference to any members of the New Zealand Division and with small local modifications other books and papers in these libraries are similarly available.

LECTURES

The list of papers and lectures given throughout the various Branches during the year is as follows. Some of these have been given at more than one Branch.

Jet Propulsion, Group Captain Watt, *Fellow*.
Early Experiences in Aviation, Squadron Leader Ellis, *Associate*.
Pressurised Cabin Aircraft, Mr. Rolfe.
Vibration Problems Associated with Aircraft Power Plants, B. G. De Bray, *Associate Fellow*.
Engine Fuels with Particular Reference to New Zealand Quality, T. T. N. Coleridge, *Associate Fellow*.
Raindrops, Flying Officer R. M. Allen, *Graduate*.
The History of Aviation in New Zealand, Leo White.
Radio Navigational Aids, R. J. Dippy.
Aircraft Engine Induction Icing, G. B. Bolt, *Associate Fellow*.
Air Foil Icing at Low Temperatures, L. N. Larsen.
The Low Drag Aerofoil, P. Hall.
A Survey of Wartime Aircraft Production in the United Kingdom, J. Simpson.
Aviation in Other Parts of the World, K. Day.

In addition a number of films were shown at meetings and also, general discussion meetings were held.

Presented to the Annual General Meeting of the Division, 10th March 1950.

(Sgd.) A. NEVILL, *President*.
(Sgd.) T. T. N. COLERIDGE, *Secretary*.

DIVISIONAL COUNCIL 1950-51

PRESIDENT

Air Vice-Marshal Sir A. de T. Nevill, K.B.E., C.B.E., B.Sc., *Associate Fellow* (Wellington)

VICE-PRESIDENT

Professor T. D. J. Leech, C.B.E., B.Sc., B.E., *Fellow* (Auckland)

SECRETARY—Mr. T. T. N. Coleridge, B.E., M.I.Mech.E., *Associate Fellow* (Wellington)

ASSIST. SECRETARY—Squadron Leader J. D. Robins, *Associate* (Wellington)

TREASURER—Mr. O. A. Kemp

COUNCIL MEMBERS

Mr. I. A. Scott, *Associate Fellow* (Wellington).
Mr. E. A. Gibson, O.B.E., A.M.I.C.E., *Associate Fellow* (Wellington)
Wing Commander G. Carter, O.B.E., *Associate Fellow* (Wellington)
Mr. A. W. Dingle, *Associate Fellow* (Palmerston North)
Mr. H. F. T. Adams, M.A., A.M.I.Mech.E., *Associate Fellow* (Christchurch)
Mr. A. H. T. Brazier, *Associate* (Christchurch)

ROYAL AERONAUTICAL SOCIETY—NEW ZEALAND DIVISION
FINANCIAL STATEMENT FOR THE YEAR ENDED 31st DECEMBER 1949

Receipts	£	s.	d.	*Expenditure*	£	s.	d.
Subscription and Entrance Fees paid in N.Z.	180	11	0	Wellington Branch—			
Transfer ex R.Ae.S. Australian Division	102	16	8	Grant	5	0	0
				Reimbursement of Subs. ...	5	15	0
				Palmerston Branch—			
				Grant	5	0	0
				Reimbursement of Subs. ...	1	15	6
				Auckland Branch—			
				Grant	5	0	0
				Reimbursement of Subs. ...	3	10	6
				Canterbury Branch—			
				Grant	5	0	0
				Reimbursement of Subs. ...	3	10	6
				Who's Who—Whites Aviation		7	6
				Bank Fees		10	0
				Record Books	1	7	8
				Postage and Stationery	6	16	3
				Miscellaneous		13	5
				Transfer to R.Ae.S. London (plus exchange)	90	18	0
				Balance at National Bank of N.Z., 31st December 1949 ...	147	0	8
				Petty Cash in hand, 31st December 1949	1	2	8
	£283	7	8		£283	7	8

I certify that these Accounts are in accordance with the books of the Society and have been audited and found correct.

(Sgd.) M. B. FURLONG
Sqdn. Ldr., R.N.Z.A.F.
Hon. Auditor

PRESIDENTIAL ADDRESS

The following address was given by Air Vice-Marshal Sir A. de T. Nevill, K.B.E., C.B.E., B.Sc., A.F.R.Ae.S., following the Annual General Meeting on 10th March 1950.

In endeavouring to find a suitable subject for an address I have been oppressed by the story of the clergyman who chose as his title for a short sermon—"Man and his relation to God in the Past, Present and Future." Certainly a somewhat ambitious subject and I fear that any general talk on aviation today is liable to the same criticism. In spite of this, I propose in the course of some 20 minutes to cover an equally wide field. I intend to say a few words about the Society and our responsibilities, to make a few generalisations about aviation in New Zealand and finally to outline in more detail progress in aeronautical research.

The Royal Aeronautical Society

We, who are members of the Society or of its Branches, are all deeply interested in the future of aviation. It is very pleasing to see so many here tonight and especially those who have no close professional interest in aviation. It is this latter class who clearly cannot be accused of bias or self-interest whose views and support are so valuable, and it is to these that my remarks are primarily addressed.

I have always remembered the words of the President of the International Civil Aviation Conference at Chicago in 1944 (Adolph Berle, a prominent American) who said at the conclusion of his opening address "All of us here assembled are in some sense trustees of the present and what we do will also influence the future in ways which we can hardly calculate. Science has vouchsafed us a great tool of international relations, and custom is beginning to teach us its use. But science leaves human and spiritual values to men; and this tool may serve or injure, unite or divide, destroy or save as men use it."

The predominant factor in world affairs will be aviation. It will make or break our world perhaps in our time. We pray that it will be an instrument of peace and goodwill.

For these reasons I think it is most appropriate that we should refresh our minds on the objects and aims of the Society. A year ago His Majesty the King granted the Royal Aeronautical Society a Charter of Incorporation. As you know, the Society was formed in 1866 by a number of men who set themselves up to advance the frontiers of aeronautical knowledge. The Society has now been charged by the King with the responsibility for the general advancement of Aeronautics throughout his Realm, and no other body in the United Kingdom or the Dominions has a like responsibility. The strength and influence of the Society in the United Kingdom is common knowledge. Membership of the Society is a privilege and a clear qualification. It is also a responsibility.

The objects and purposes for which the Society is constituted are set out in the Royal Charter. They are the general advancement of Aeronautical Art, Science and Engineering and more particularly the species of knowledge which distinguishes the profession of aeronautics. These objects are furthered in many ways, among which are the regular meetings of the Society and its Branches, the promotion of exhibitions, the establishment of libraries, the encouragement of invention and research, the promotion of education and the offer of advice in aeronautical matters. The New Zealand Division has accepted these responsibilities and it is the duty of your Council to support all those activities which further the development of aviation in the Dominion and especially the application of aviation to the exploitation of the natural resources of this country.

Aviation in New Zealand

It is quite unnecessary to make a case for the development of aviation in this country. Sufficient to say that if we wish to remain in the van of progress (and we must do so if we are going to retain this country in the future) we must rely in a large measure on aviation. New Zealand is a country of two million people with relatively undeveloped road, rail and sea communications, and there is a *prima facie* case for the proper co-ordination, at this stage in our history, of all forms of transport according to their inherent characteristics. From the aviation point of view New Zealand consists of a group of fertile islands with a rugged terrain which adds considerably to the engineering difficulties and costs of any marked improvement in road and rail facilities. Furthermore, as distinct from ordinary transport, there are many ways in which aircraft can be employed to develop the natural resources of the Dominion.

The position of aviation in New Zealand can best be examined under certain broad headings, all of which must be present in varying degrees and all of which affect the successful development of aviation. These are in order of importance as follows: first and most important, the general public, without whose enlightened support there can be no progress at all. Next comes the visible and outward sign of

progress in aviation—the aircraft operating companies, clubs and private flying in the Dominion. Closely tied up with these activities is the administration responsible for the ground facilities for aviation and the regulation and safety of flying. Then we have the aviation industry, some element of which is indispensable to a country making any appreciable use of aviation in its national economy. Finally, and not the least important, is the research of an operational and technical nature, which may be both applied and fundamental, carried out in the Dominion.

These are the ingredients of the modern aviation cake and they must all be present if the cake is to be popular, nutritious and cheap. I propose to restrict any further comment to these items, which are either so obviously important (like the general public) that they are rarely discussed, or which are so neglected, like industry and research, that their importance is overlooked.

Education

First, the public attitude towards aviation. It may be accepted as fundamental that the development of aviation in a democratic community depends mainly upon the outlook and knowledge of the general public. It is often said that New Zealanders are "air minded," a statement which arises from the amount of flying per head done in New Zealand, but this is due to the fact that we are a fairly intelligent community with advanced standards of life, who expect the amenities of air transport. I feel that we are somewhat uncritical and unimaginative in our outlook towards aviation and I doubt whether there is that sound basic understanding which is essential to the healthy development of aviation and the full enjoyment of all its benefits. I doubt, for example, whether it is appreciated that the air is a completely new medium for human activities of a most diverse nature. Most certainly, aviation is not just another form of transport subject to the old rules and techniques.

It is perhaps too much to expect our adult community to recognise fully this, but it is essential that the rising generation should enter upon their duties fully equipped and aware of the problems to be faced in the new age before us. For better or worse aviation will have far-reaching and incalculable effects on the social life of the peoples of the world. Aviation has set the problem but it also offers the solution. It is only by the more extensive use of aviation that the idea of world community, at least throughout the democratic nations, becomes administratively practicable. I have been surprised at the extent to which aeronautical subjects and studies on the social implications of aviation have been injected elsewhere (particularly in the U.S.A.) into secondary school and university education. I would earnestly commend a study of these matters to our educational authorities.

The Aviation Industry

There is no industry as such in New Zealand today, although a certain amount of assembly, repair and maintenance is carried out by a few companies not otherwise associated with the business of air transport. There is no great difficulty in the manufacture of a modern airframe, although it would be necessary to draw extensively on the experience of established firms. It is a light industry which could otherwise be as well developed in New Zealand as elsewhere. The manufacture of aviation power plants, which requires more diversified processes and a larger backing of heavy industry, is a rather different problem and the manufacture of many components and instruments to modern standards is always likely to be restricted to a limited number of major industrial nations. It is customary to deride the possibility of manufacturing aircraft in New Zealand on the grounds of the high cost involved for the limited numbers required, but these are merely vague generalisations which have received no critical examinations. Today we have a better knowledge of costs and requirements. Furthermore in the transport field below 200 m.p.h., design is reaching a fairly static condition, and there is reason to think that development costs, which constitute such a large proportion of the cost of new aircraft, will be largely eliminated in this field.

What are our major aviation requirements and what are the limitations? This is a country of very short airline distances between the major centres. With present speeds the block to block time involved in air travel is under two hours anywhere. There is little to be gained in passenger transport by any appreciable increase in speed. Safety, economy and service should be the guiding principles in the application of aviation to New Zealand conditions. The best interests of New Zealand over the next decade at least, would be served by the modification of one of the well-established British types to New Zealand conditions for extensive use in New Zealand for Air Force and Commercial Aviation, for freight, passengers and miscellaneous duties. Such a type should be a basic airframe of about 40,000 lb. all-up weight equipped with two medium, or four light, engines of a well proved and simple design, capable of using aerodromes to class E standard. If we were wise enough and bold enough to concentrate on one basic airframe and power plant of cheap and rugged design for the next decade as a general utility aerial bus and freighter, great economies would follow. The numbers required would justify also the development of a small aviation industry which in itself has a considerable defence potential.

Aeronautical Research

While New Zealand's participation in aeronautical research has been negligible, there are solid grounds for believing that New Zealand will take its full share in the future. Time alone will produce a useful body of research workers and only then if they are given adequate opportunities for training and research, both within New Zealand and overseas. The organisation is fairly complete. The New Zealand Aeronautical Research Council is linked with the Commonwealth Council from which it receives advice on research activity. Two centres primarily for basic research are being developed and equipped at the School of Engineering, Auckland, and the Canterbury University College. An adequate liaison exists between the Department of Scientific and Industrial Research, The Royal New Zealand Air Force, and Civil Aviation, on research matters. The Dominion Physical Laboratory is well equipped for the supply of specialised equipment and instruments required for research. Furthermore, provision is made both through the annual Government scholarship to the College of Aeronautics and through the Defence Science Corps to build up a body of aeronautical research workers; unique opportunities are offered to a limited number of New Zealand Honours graduates to obtain through the Defence Science Corps the most advanced post-graduate instruction in the United Kingdom. In this way we should build up a small body of suitable scientific personnel for aeronautical research both within New Zealand and overseas. As Sir Henry Tizard has emphasised, this is only a beginning and to my mind it will be a serious reflection on our whole educational system unless our universities are capable of producing greater numbers of really high grade material.

Such a scheme will not be successful unless we can employ an adequate proportion of such personnel within New Zealand at our universities and other scientific establishments. It is a complete fallacy that all such research can only be adequately undertaken within large and well-equipped aeronautical research establishments. Moreover, it is dangerous to develop aviation in this country without some research backing capable of investigating *ad hoc* problems, both operational and technical, which arise from time to time. It is hoped that an operational research flight may be built up within the R.N.Z.A.F. for such investigations, working closely with the two universities. These two universities should be provided with certain basic equipment. At least one General Purpose Wind Tunnel, necessary both for basic and applied research, should be constructed in New Zealand as early as possible. A programme of basic research is already under way at the universities, but these activities will be greatly hampered unless more emphasis is placed on the need for adequate research facilities.

In the more practical field of research involving the use of the aeroplane, a considerable range of activities are gradually opening up. The Air Force has made

aircraft available for meteorological and radar investigations of the Fohn wind conditions in Canterbury, for investigations of cosmic ray intensity at high altitude, and is now proceeding with magnetic surveys of power and mineral resources using an airborne magnetometer.

In addition, the aeroplane has a great range of utility in many ancillary roles of direct economic importance to New Zealand. These include aerial surveys for mapping, forestry and geological purposes, forestry fire patrols, aerial spraying of forests, orchards and crops against disease, the use of aircraft to prevent frost damage, aerial top dressing and seeding for farmers, soil conservation activities in the form of planting to prevent erosion due to action of the sea, sand and weather, fishery patrols, the support of ground parties in isolated and inaccessible areas, search, rescue and hospital work, and general emergency measures to deal with natural disasters such as flood, earthquake, forest fires and epidemics and so on.

Conclusion

To a dispassionate observer of the world today, who takes a long-term view, it would appear that New Zealanders are living in a fool's paradise. We have a moral right to retain this country only if we demonstrate that we are making full use of it in spite of our relatively small population. This means the application of science to the more intensive production of foodstuffs and the exploitation of our other natural resources. At the same time, in this uncertain world, our military strength must at least be sufficient to deter any aggressive nation which would otherwise find New Zealand an attractive acquisition. The popular belief is that we cannot do so, but given a population of, say five million, enjoying our present living standards and other advantages, this country, located as it is in the South Pacific, could defend itself against any likely scale of attack.

In these matters of developing the resources of New Zealand and of defending our heritage, aviation will play a leading role in the future. It is incumbent therefore on all those with the long-term interest of the Dominion at heart, to bend their energies to the development of aviation. In this way we will exploit more fully the natural resources of New Zealand and at the same time contribute more effectively to the defence of the country.

an appreciation

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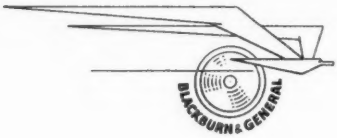

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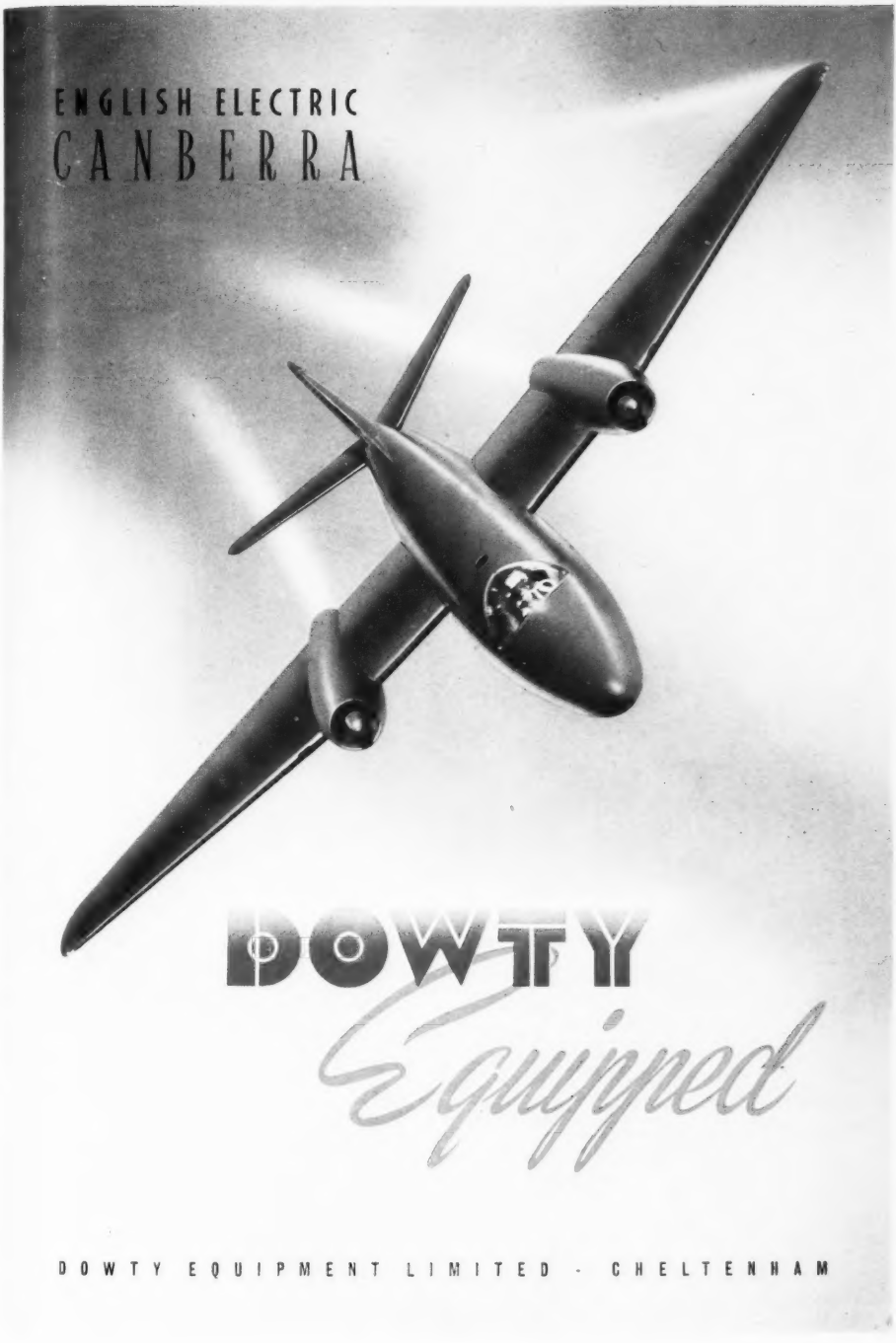

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